US008005460B2

(12) **United States Patent**
Chen et al.

(10) **Patent No.: US 8,005,460 B2**
(45) **Date of Patent: Aug. 23, 2011**

(54) **GROUP AUTHENTICATION METHOD**

(75) Inventors: **Yu-Wen Chen**, Taichung (TW); **Jui-Tang Wang**, Keelung (TW); **Chien-Chao Tseng**, Hsinchu (TW)

(73) Assignees: **Industrial Technology Research Institute**, Hsinchu (TW); **National Chiao Tung University**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 832 days.

(21) Appl. No.: **12/025,771**

(22) Filed: **Feb. 5, 2008**

(65) **Prior Publication Data**

US 2009/0054036 A1 Feb. 26, 2009

(30) **Foreign Application Priority Data**

Aug. 24, 2007 (TW) .... 96131436 A

(51) **Int. Cl.**
H04M 3/16 (2006.01)

(52) **U.S. Cl.** **455/411**; 340/5.8; 379/142.05; 380/229; 380/232; 380/233

(58) **Field of Classification Search** 455/411; 340/5.8; 379/142.05; 380/229, 232, 233
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,668,875	A *	9/1997	Brown et al.	380/248
6,915,426	B1 *	7/2005	Carman et al.	713/168
7,683,773	B1 *	3/2010	Goodall et al.	340/505
2004/0151140	A1 *	8/2004	Rozenblit et al.	370/335
2005/0141720	A1 *	6/2005	Watanabe et al.	380/279
2006/0050869	A1 *	3/2006	Tuvell et al.	380/28
2006/0107047	A1 *	5/2006	Bar-El	713/168
2007/0280169	A1 *	12/2007	Cam Winget	370/331
2008/0162927	A1 *	7/2008	Wang et al.	713/155

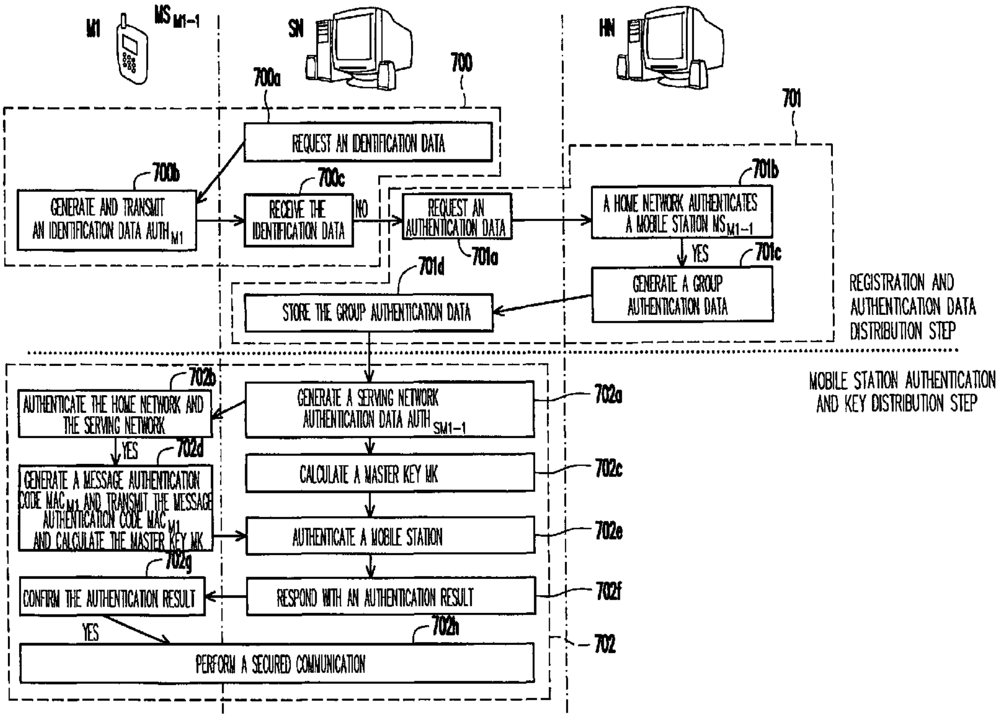
* cited by examiner

Primary Examiner — Jinsong Hu
Assistant Examiner — Qun Shen
(74) *Attorney, Agent, or Firm* — Jianq Chyun IP Office

(57) **ABSTRACT**

A group authentication method adaptable to a communication system is disclosed. The communication system includes a user group, a serving network, and a home network. The user group includes at least one mobile station. The home network pre-distributes a group authentication key to itself and all the mobile stations in the same user group and generates a mobile station authentication key for each mobile station. The home network generates a group list for recording related information of the user group. The home network has a database for recording the group list. The serving network has a database for recording the group list and a group authentication data received from the home network. The group authentication method includes following steps. The serving network performs an identification action to a mobile station. The communication system performs a full authentication action or a local authentication action according to the result of the identification action.

29 Claims, 24 Drawing Sheets


M1
MS$_{M1-1}$
SN
HN
700
700a
REQUEST AN IDENTIFICATION DATA
700b
GENERATE AND TRANSMIT AN IDENTIFICATION DATA AUTH$_{M1}$
700c
RECEIVE THE IDENTIFICATION DATA
NO
REQUEST AN AUTHENTICATION DATA
701a
701
701b
A HOME NETWORK AUTHENTICATES A MOBILE STATION MS$_{M1-1}$
YES
701c
GENERATE A GROUP AUTHENTICATION DATA
701d
STORE THE GROUP AUTHENTICATION DATA
REGISTRATION AND AUTHENTICATION DATA DISTRIBUTION STEP
MOBILE STATION AUTHENTICATION AND KEY DISTRIBUTION STEP
702b
AUTHENTICATE THE HOME NETWORK AND THE SERVING NETWORK
GENERATE A SERVING NETWORK AUTHENTICATION DATA AUTH$_{SM1-1}$
702a
YES
702d
GENERATE A MESSAGE AUTHENTICATION CODE MAC$_{M1}$ AND TRANSMIT THE MESSAGE AUTHENTICATION CODE MAC$_{M1}$ AND CALCULATE THE MASTER KEY MK
CALCULATE A MASTER KEY MK
702c
AUTHENTICATE A MOBILE STATION
702e
702g
CONFIRM THE AUTHENTICATION RESULT
RESPOND WITH AN AUTHENTICATION RESULT
702f
YES
702h
PERFORM A SECURED COMMUNICATION
702

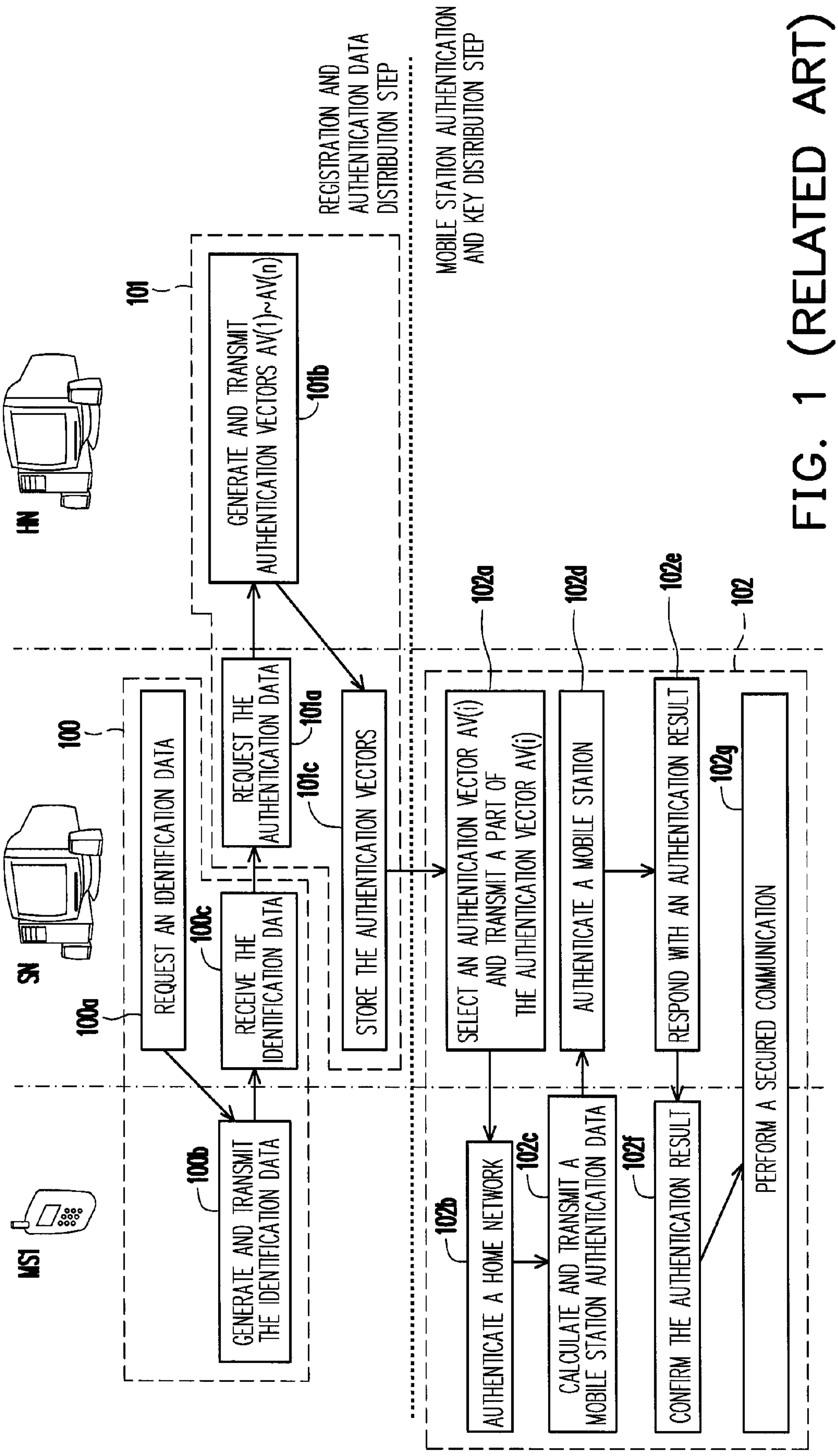

MS1
SN
HN
100
100a
REQUEST AN IDENTIFICATION DATA
100b
GENERATE AND TRANSMIT THE IDENTIFICATION DATA
100c
RECEIVE THE IDENTIFICATION DATA
101
101a
REQUEST THE AUTHENTICATION DATA
101b
GENERATE AND TRANSMIT AUTHENTICATION VECTORS AV(1)~AV(n)
101c
STORE THE AUTHENTICATION VECTORS
REGISTRATION AND AUTHENTICATION DATA DISTRIBUTION STEP
MOBILE STATION AUTHENTICATION AND KEY DISTRIBUTION STEP
102
102a
SELECT AN AUTHENTICATION VECTOR AV(i) AND TRANSMIT A PART OF THE AUTHENTICATION VECTOR AV(i)
102b
AUTHENTICATE A HOME NETWORK
102c
CALCULATE AND TRANSMIT A MOBILE STATION AUTHENTICATION DATA
102d
AUTHENTICATE A MOBILE STATION
102e
RESPOND WITH AN AUTHENTICATION RESULT
102f
CONFIRM THE AUTHENTICATION RESULT
102g
PERFORM A SECURED COMMUNICATION

FIG. 1 (RELATED ART)

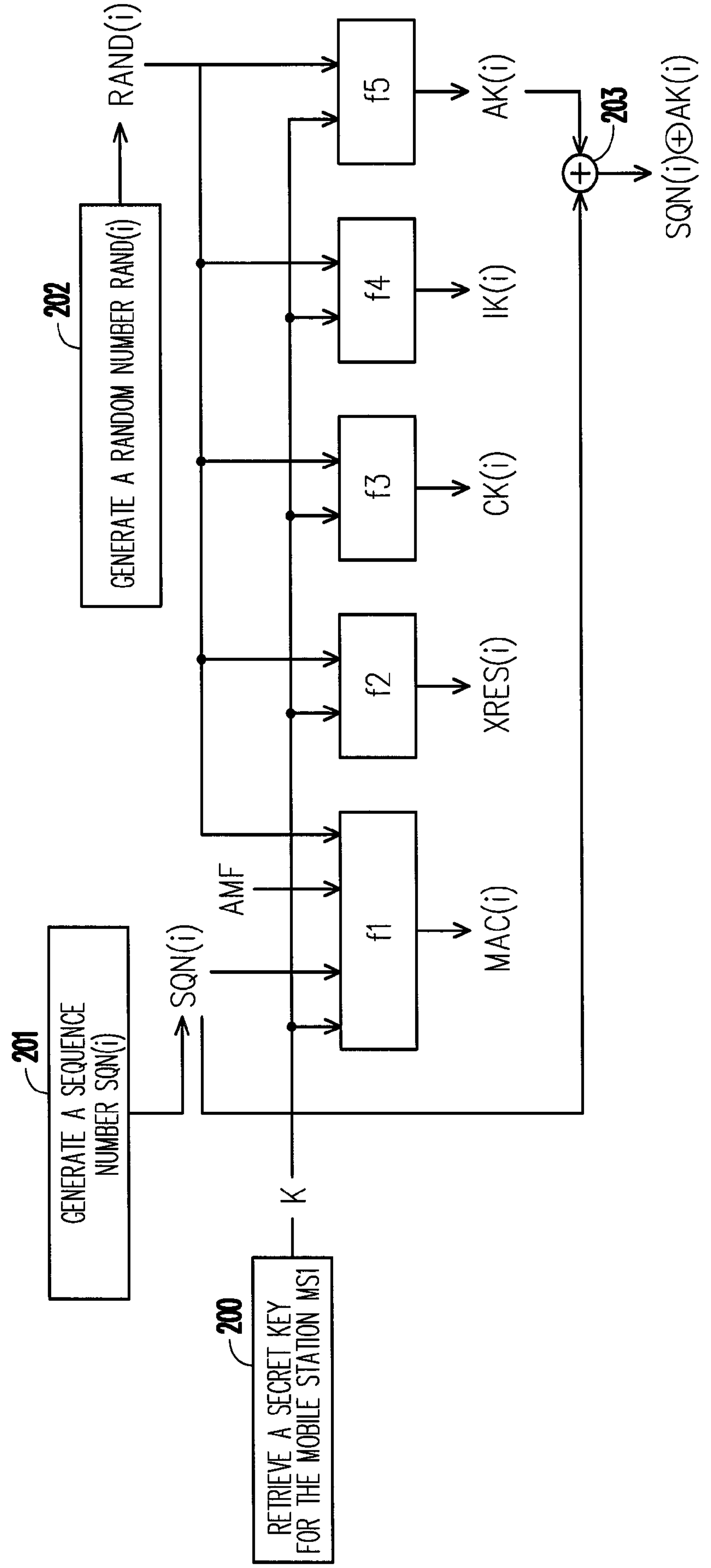

200
RETRIEVE A SECRET KEY FOR THE MOBILE STATION MS1
K
201
GENERATE A SEQUENCE NUMBER SQN(i)
SQN(i)
AMF
f1
MAC(i)
f2
XRES(i)
f3
CK(i)
f4
IK(i)
f5
AK(i)
202
GENERATE A RANDOM NUMBER RAND(i)
RAND(i)
203
SQN(i)⊕AK(i)

FIG. 2 (RELATED ART)

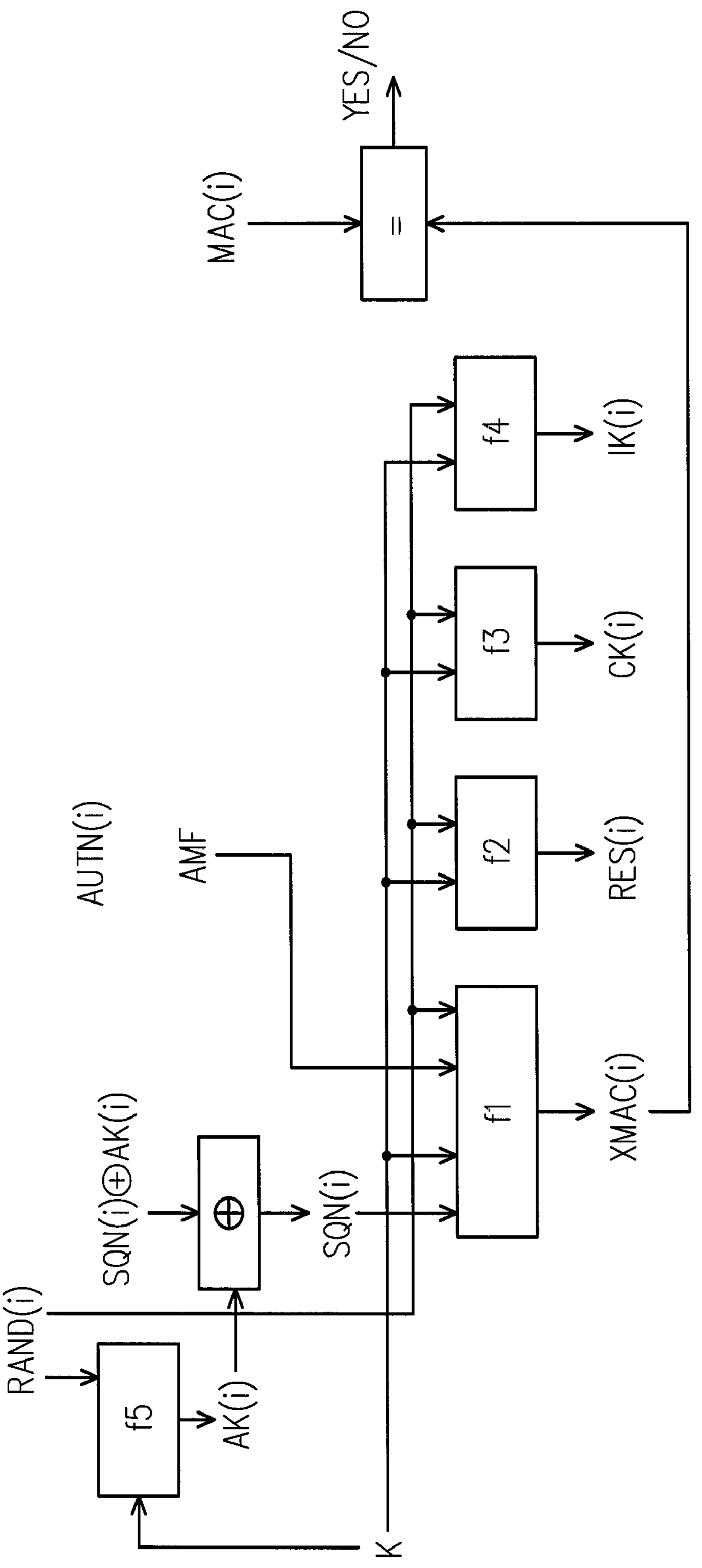


FIG. 3 (RELATED ART)

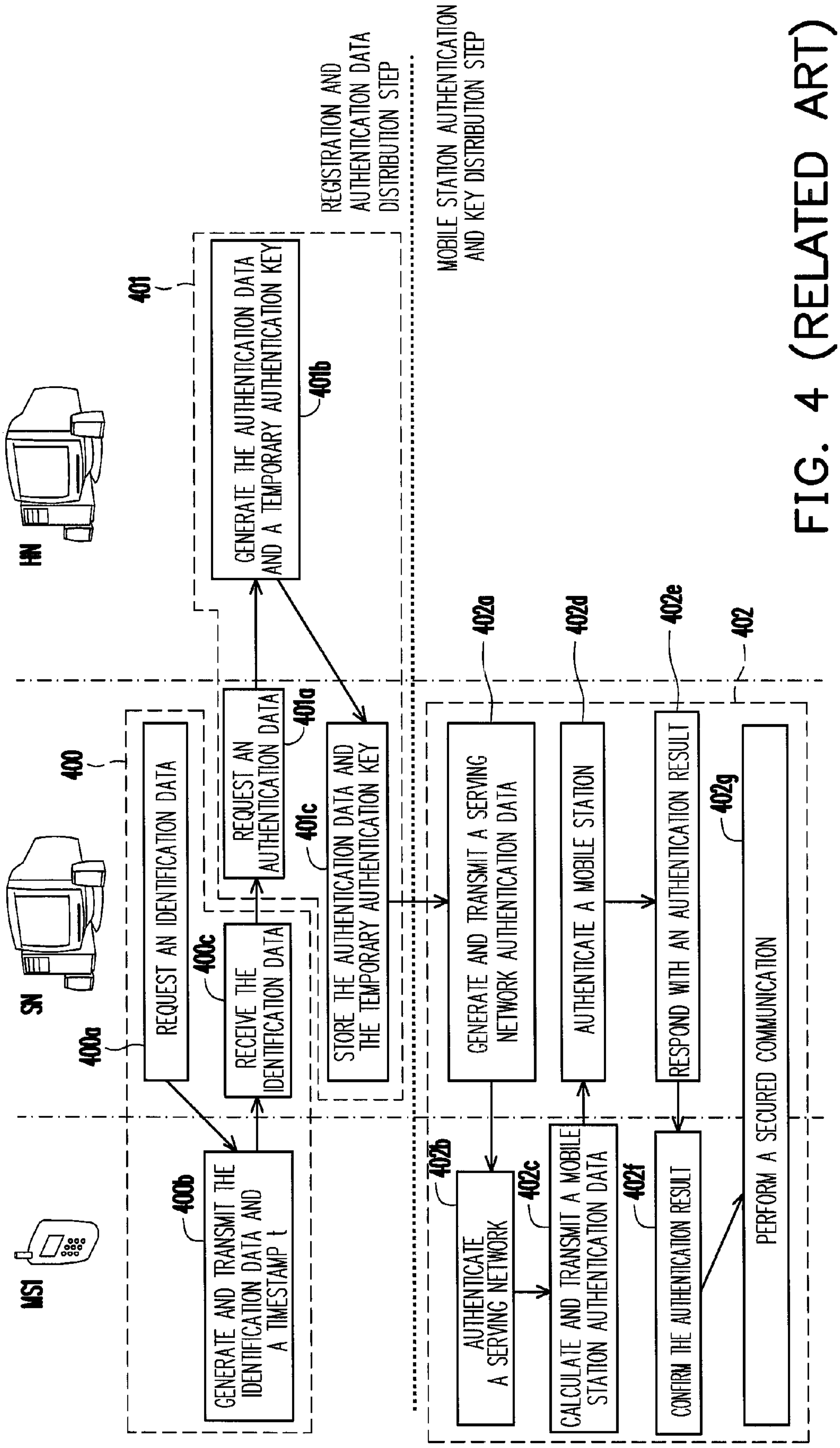

MS1
SN
HN
400
400a
REQUEST AN IDENTIFICATION DATA
400b
GENERATE AND TRANSMIT THE IDENTIFICATION DATA AND A TIMESTAMP t
400c
RECEIVE THE IDENTIFICATION DATA
401
401a
REQUEST AN AUTHENTICATION DATA
401b
GENERATE THE AUTHENTICATION DATA AND A TEMPORARY AUTHENTICATION KEY
401c
STORE THE AUTHENTICATION DATA AND THE TEMPORARY AUTHENTICATION KEY
REGISTRATION AND AUTHENTICATION DATA DISTRIBUTION STEP
MOBILE STATION AUTHENTICATION AND KEY DISTRIBUTION STEP
402
402a
GENERATE AND TRANSMIT A SERVING NETWORK AUTHENTICATION DATA
402b
AUTHENTICATE A SERVING NETWORK
402c
CALCULATE AND TRANSMIT A MOBILE STATION AUTHENTICATION DATA
402d
AUTHENTICATE A MOBILE STATION
402e
RESPOND WITH AN AUTHENTICATION RESULT
402f
CONFIRM THE AUTHENTICATION RESULT
402g
PERFORM A SECURED COMMUNICATION

FIG. 4 (RELATED ART)

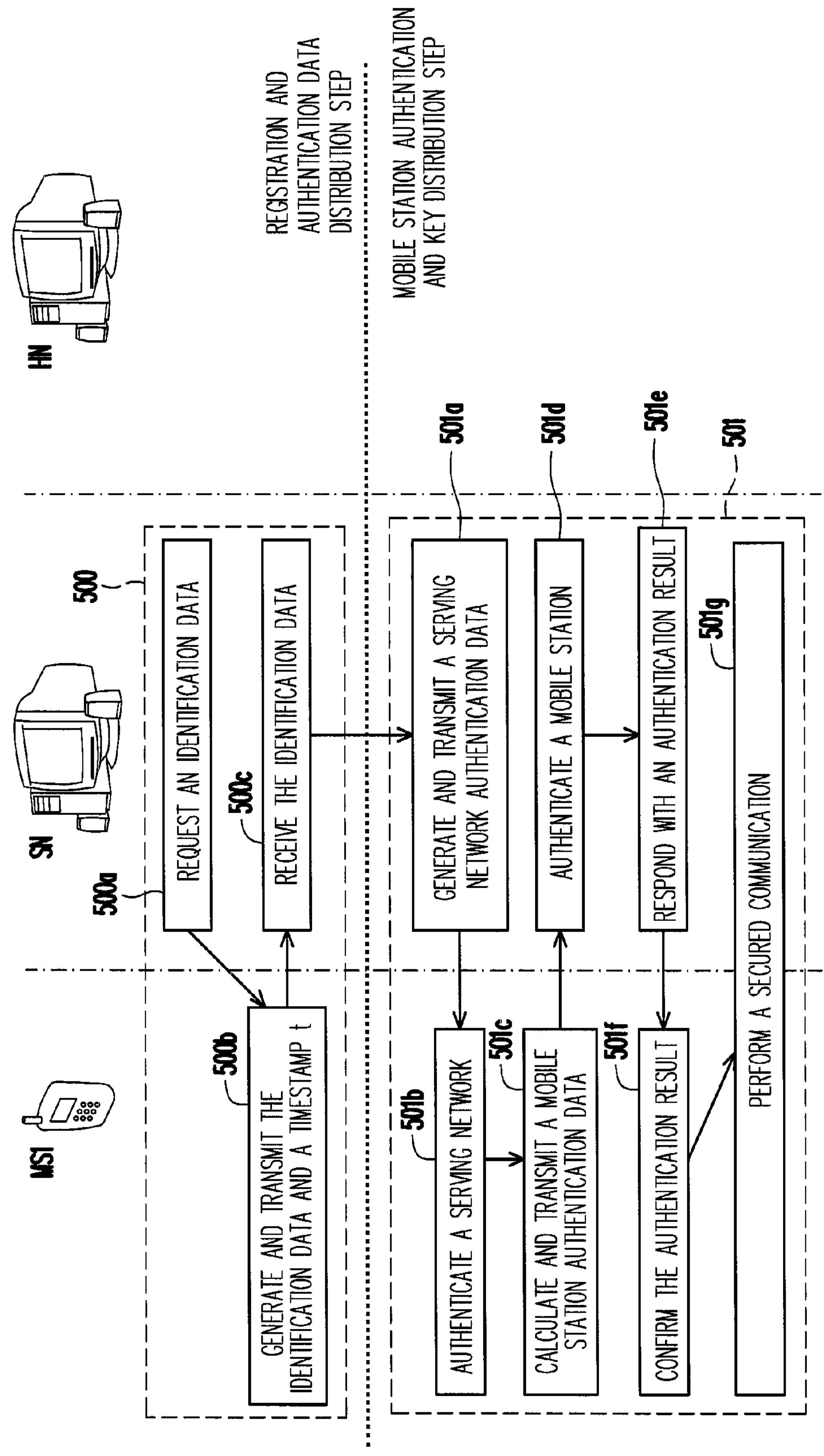

MS1
SN
HN
REGISTRATION AND AUTHENTICATION DATA DISTRIBUTION STEP
MOBILE STATION AUTHENTICATION AND KEY DISTRIBUTION STEP
500
500a
REQUEST AN IDENTIFICATION DATA
500b
GENERATE AND TRANSMIT THE IDENTIFICATION DATA AND A TIMESTAMP t
500c
RECEIVE THE IDENTIFICATION DATA
501
501a
GENERATE AND TRANSMIT A SERVING NETWORK AUTHENTICATION DATA
501b
AUTHENTICATE A SERVING NETWORK
501c
CALCULATE AND TRANSMIT A MOBILE STATION AUTHENTICATION DATA
501d
AUTHENTICATE A MOBILE STATION
501e
RESPOND WITH AN AUTHENTICATION RESULT
501f
CONFIRM THE AUTHENTICATION RESULT
501g
PERFORM A SECURED COMMUNICATION

FIG. 5 (RELATED ART)

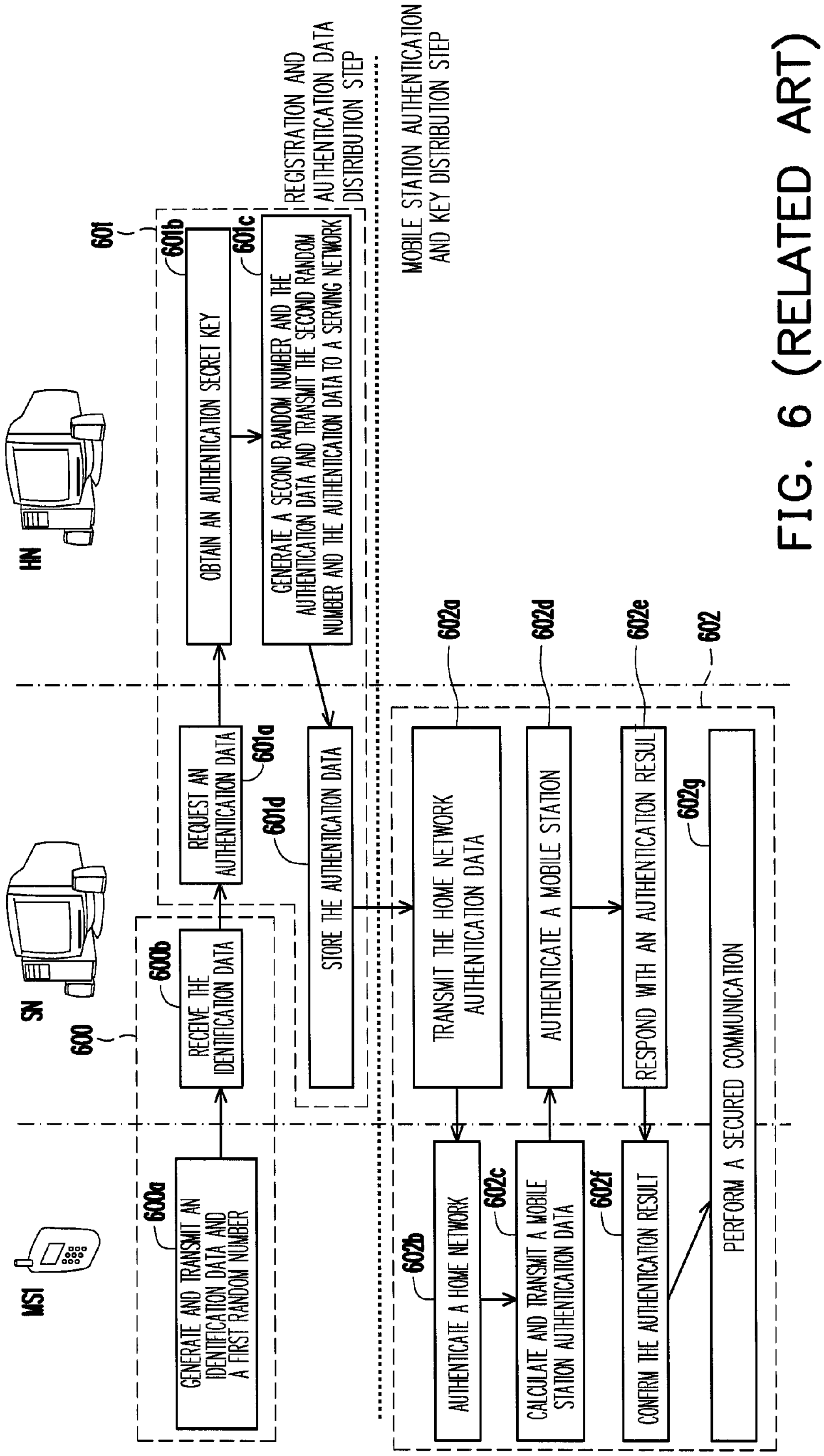

MS1
SN
HN
600
600a
GENERATE AND TRANSMIT AN IDENTIFICATION DATA AND A FIRST RANDOM NUMBER
600b
RECEIVE THE IDENTIFICATION DATA
601
601a
REQUEST AN AUTHENTICATION DATA
601b
OBTAIN AN AUTHENTICATION SECRET KEY
601c
GENERATE A SECOND RANDOM NUMBER AND THE AUTHENTICATION DATA AND TRANSMIT THE SECOND RANDOM NUMBER AND THE AUTHENTICATION DATA TO A SERVING NETWORK
601d
STORE THE AUTHENTICATION DATA
REGISTRATION AND AUTHENTICATION DATA DISTRIBUTION STEP
MOBILE STATION AUTHENTICATION AND KEY DISTRIBUTION STEP
602
602a
TRANSMIT THE HOME NETWORK AUTHENTICATION DATA
602b
AUTHENTICATE A HOME NETWORK
602c
CALCULATE AND TRANSMIT A MOBILE STATION AUTHENTICATION DATA
602d
AUTHENTICATE A MOBILE STATION
602e
RESPOND WITH AN AUTHENTICATION RESUL
602f
CONFIRM THE AUTHENTICATION RESULT
602g
PERFORM A SECURED COMMUNICATION

FIG. 6 (RELATED ART)

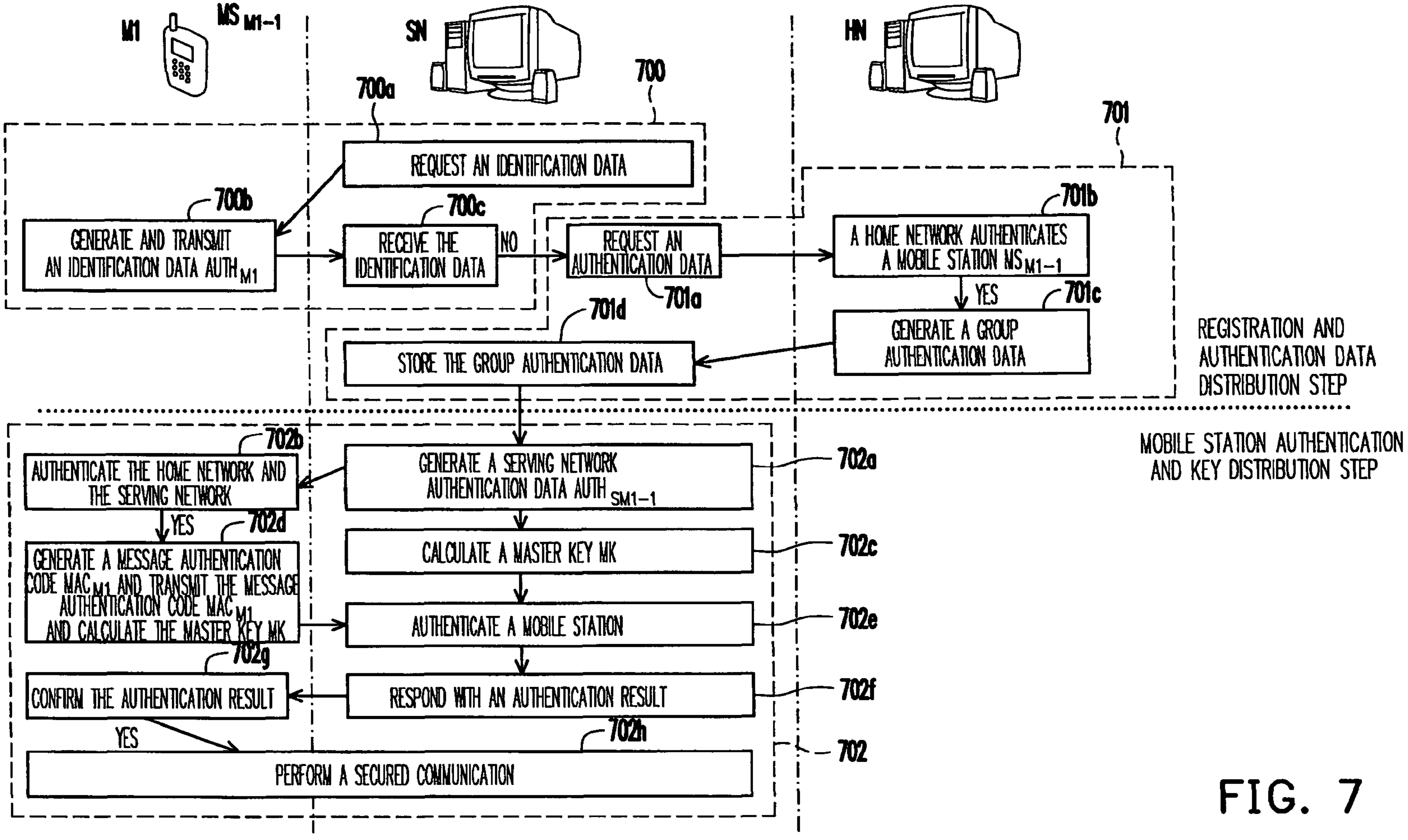

M1
MS_{M1-1}
SN
HN
700
700a
REQUEST AN IDENTIFICATION DATA
700b
GENERATE AND TRANSMIT AN IDENTIFICATION DATA $AUTH_{M1}$
700c
RECEIVE THE IDENTIFICATION DATA
NO
REQUEST AN AUTHENTICATION DATA
701a
701
701b
A HOME NETWORK AUTHENTICATES A MOBILE STATION MS_{M1-1}
YES
701c
GENERATE A GROUP AUTHENTICATION DATA
701d
STORE THE GROUP AUTHENTICATION DATA
REGISTRATION AND AUTHENTICATION DATA DISTRIBUTION STEP
MOBILE STATION AUTHENTICATION AND KEY DISTRIBUTION STEP
702b
AUTHENTICATE THE HOME NETWORK AND THE SERVING NETWORK
GENERATE A SERVING NETWORK AUTHENTICATION DATA $AUTH_{SM1-1}$
702a
YES
702d
GENERATE A MESSAGE AUTHENTICATION CODE MAC_{M1} AND TRANSMIT THE MESSAGE AUTHENTICATION CODE MAC_{M1} AND CALCULATE THE MASTER KEY MK
CALCULATE A MASTER KEY MK
702c
AUTHENTICATE A MOBILE STATION
702e
702g
CONFIRM THE AUTHENTICATION RESULT
RESPOND WITH AN AUTHENTICATION RESULT
702f
YES
702h
PERFORM A SECURED COMMUNICATION
702

FIG. 7

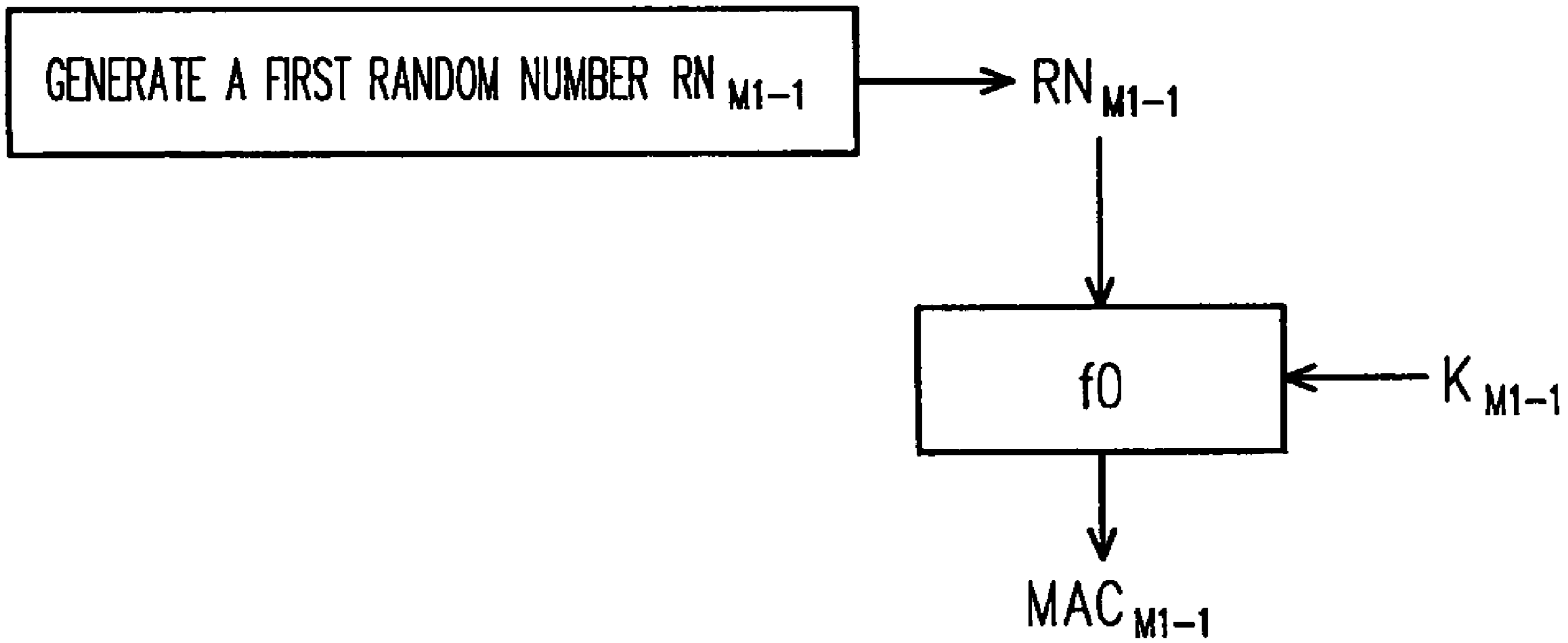


FIG. 8

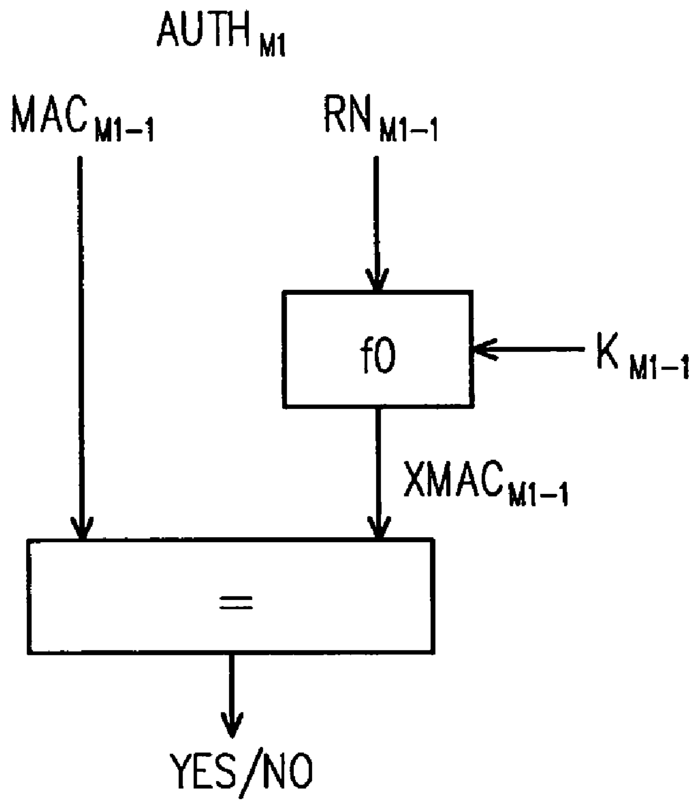


FIG. 9

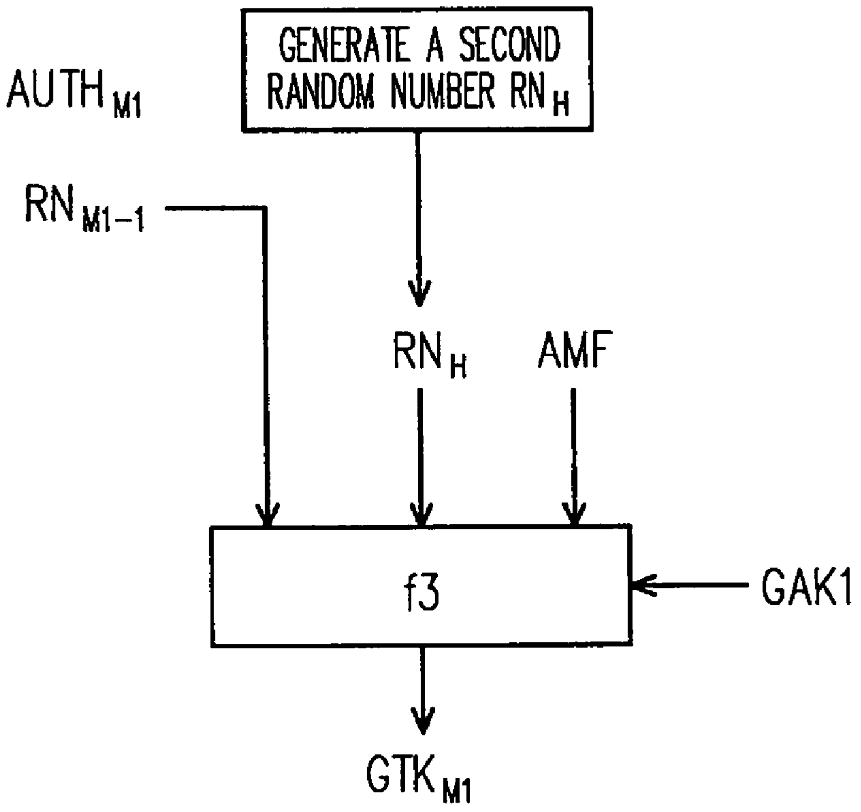

GENERATE A SECOND RANDOM NUMBER RN_H
$AUTH_{M1}$
RN_{M1-1}
RN_H
AMF
f3
GAK1
GTK_{M1}

FIG. 10

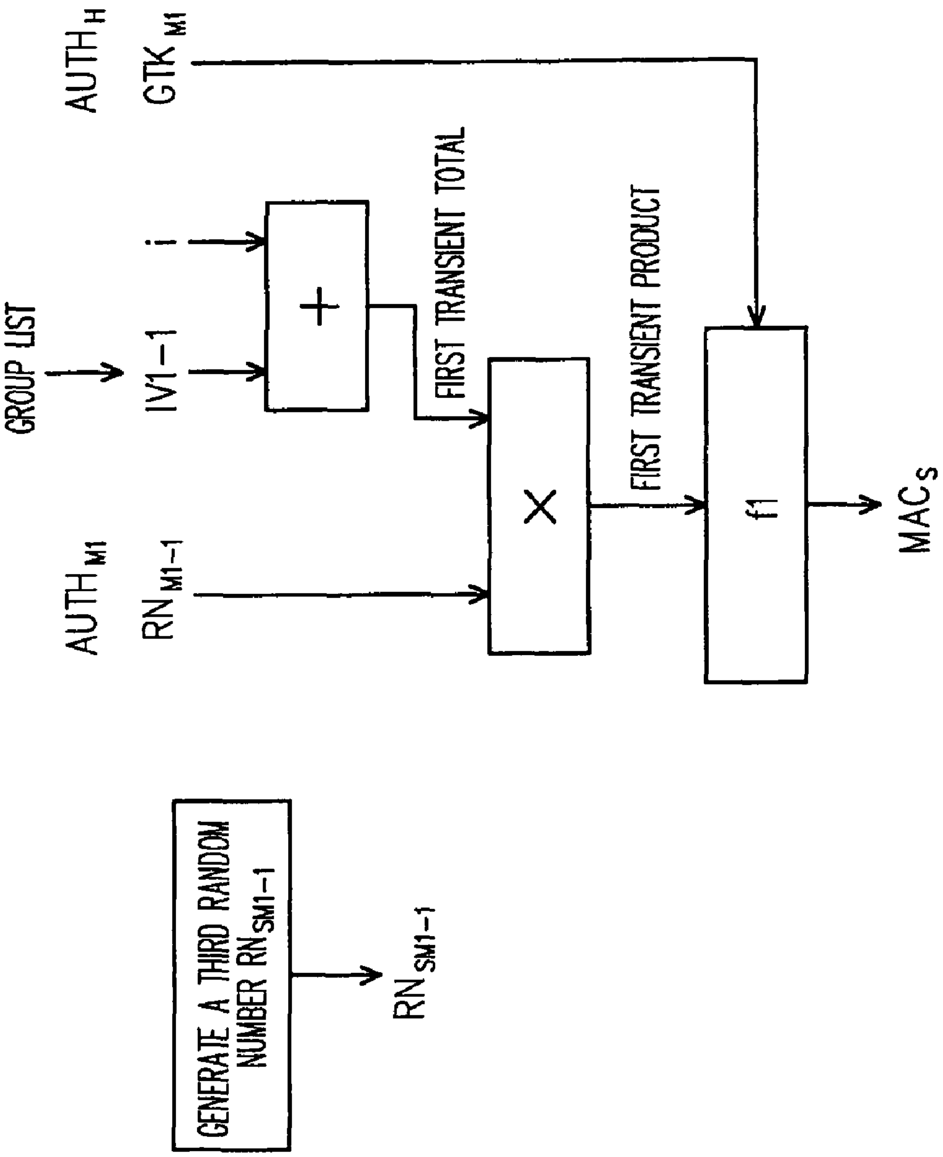

AUTH$_H$
GTK$_{M1}$
GROUP LIST
IV1−1
i
+
FIRST TRANSIENT TOTAL
AUTH$_{M1}$
RN$_{M1-1}$
×
FIRST TRANSIENT PRODUCT
f1
MAC$_S$
GENERATE A THIRD RANDOM NUMBER RN$_{SM1-1}$
RN$_{SM1-1}$

FIG. 11

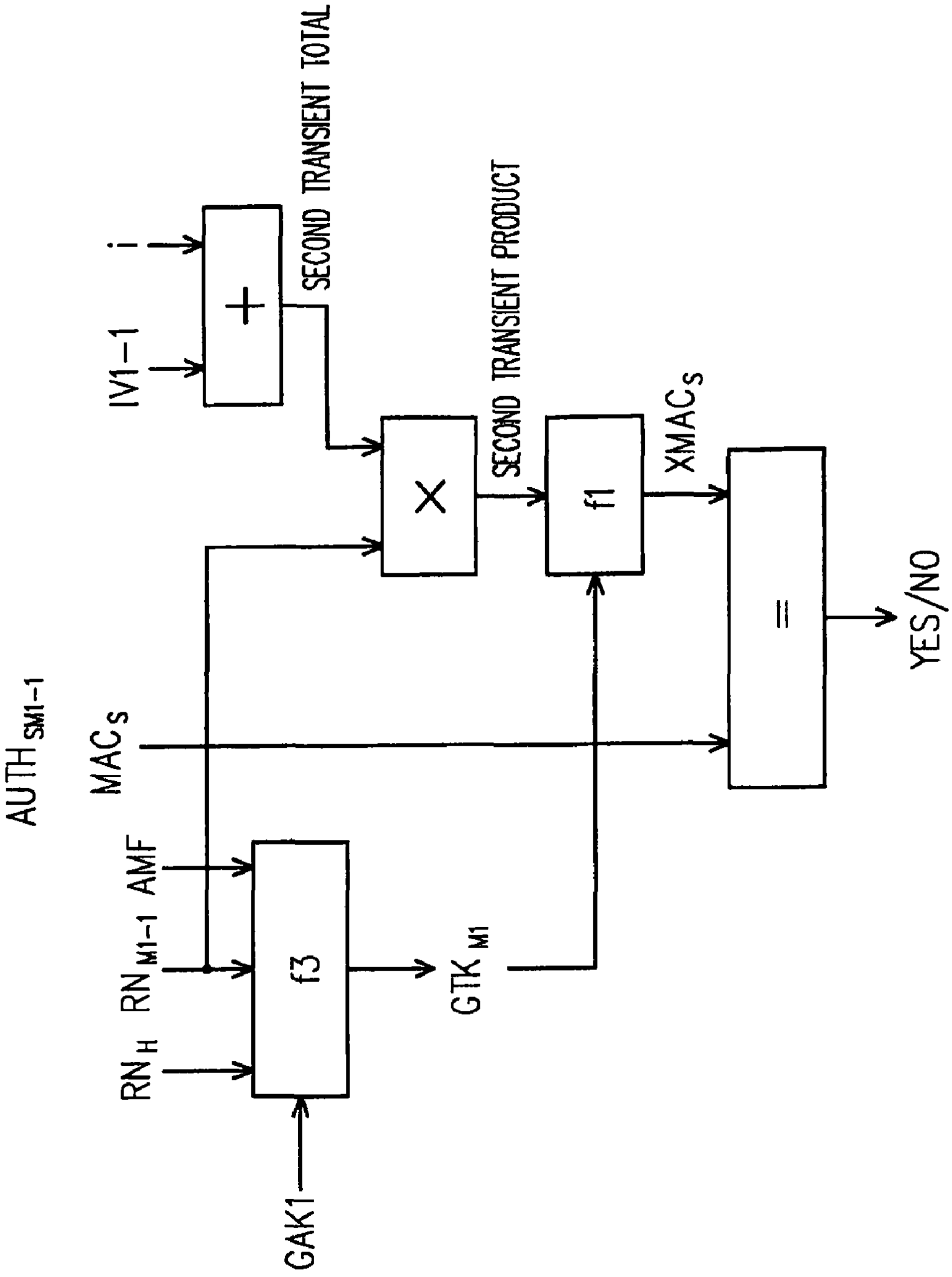

AUTH$_{SM1-1}$
MAC$_S$
RN$_H$
RN$_{M1-1}$
AMF
GAK1
f3
GTK$_{M1}$
IV1-1
i
+
SECOND TRANSIENT TOTAL
×
SECOND TRANSIENT PRODUCT
f1
XMAC$_S$
=
YES/NO

FIG. 12

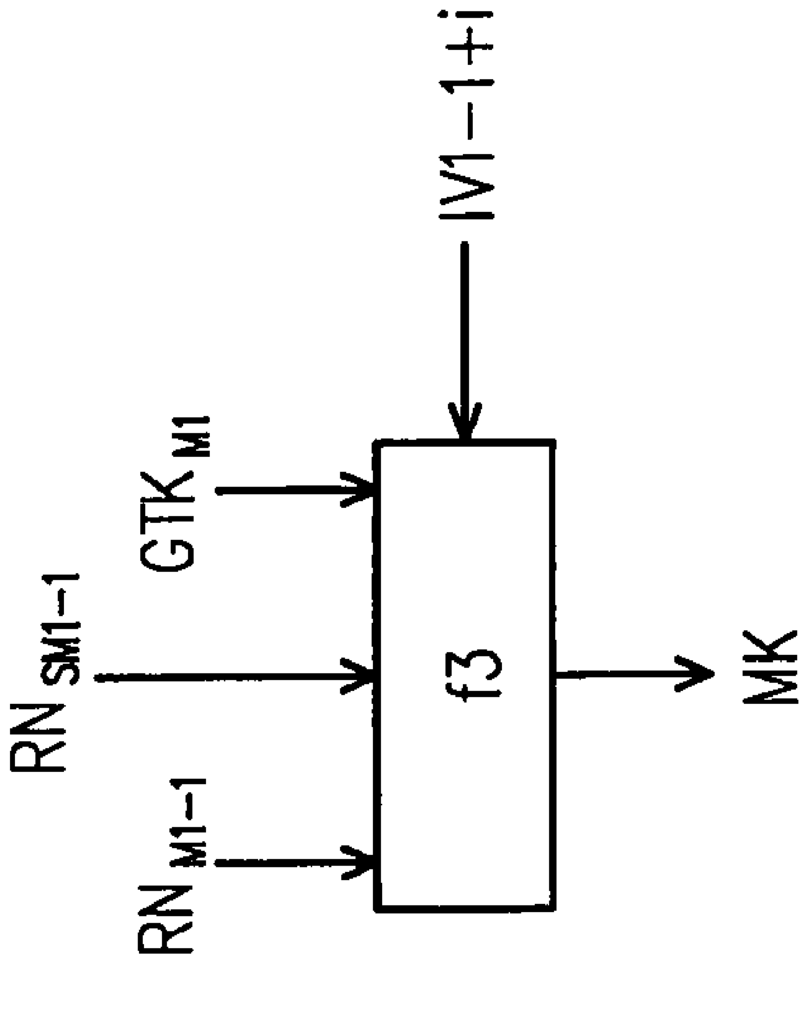


FIG. 13

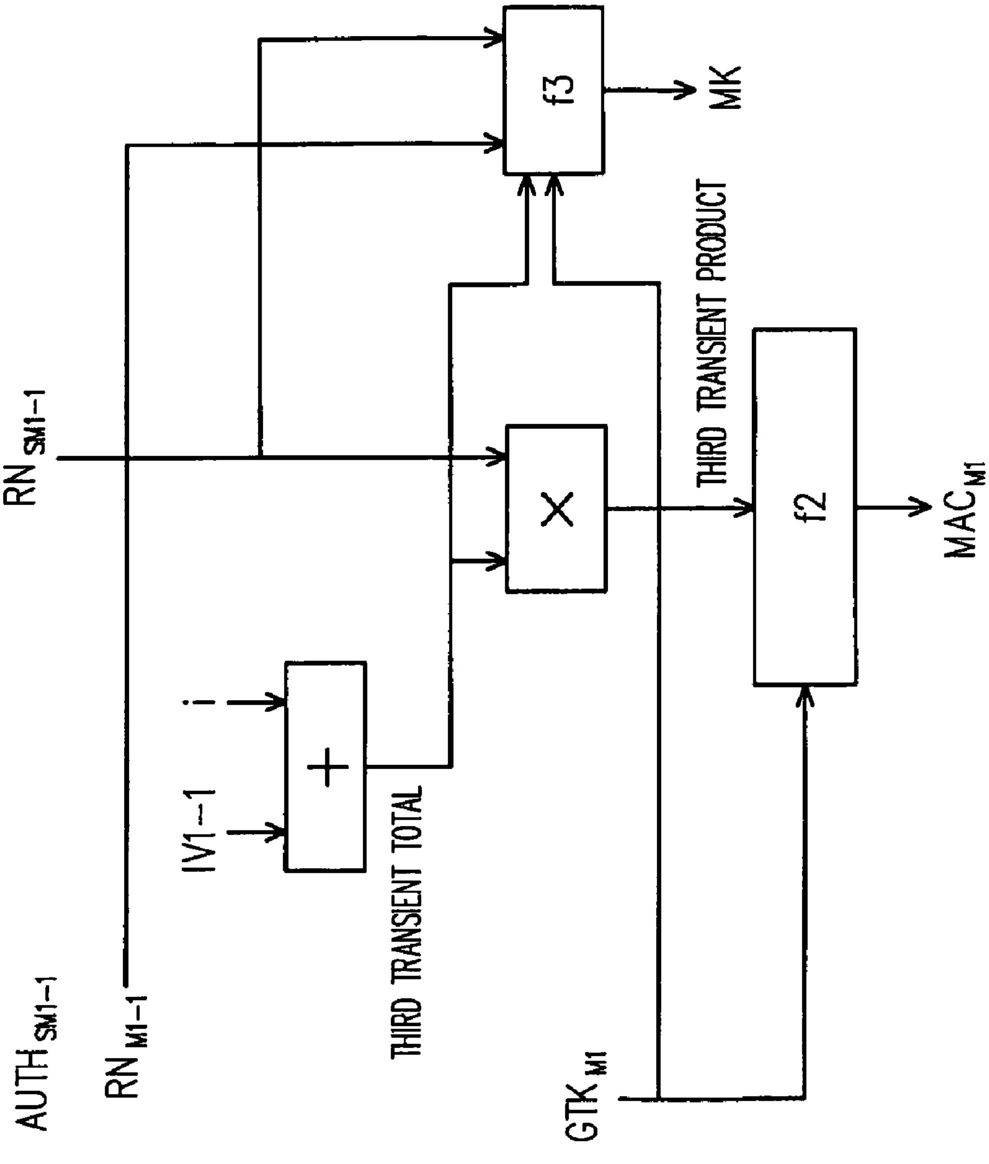

AUTH$_{SM1-1}$
RN$_{M1-1}$
RN$_{SM1-1}$
IV1-1
i
+
THIRD TRANSIENT TOTAL
×
f3
MK
THIRD TRANSIENT PRODUCT
f2
MAC$_{M1}$
GTK$_{M1}$

FIG. 14

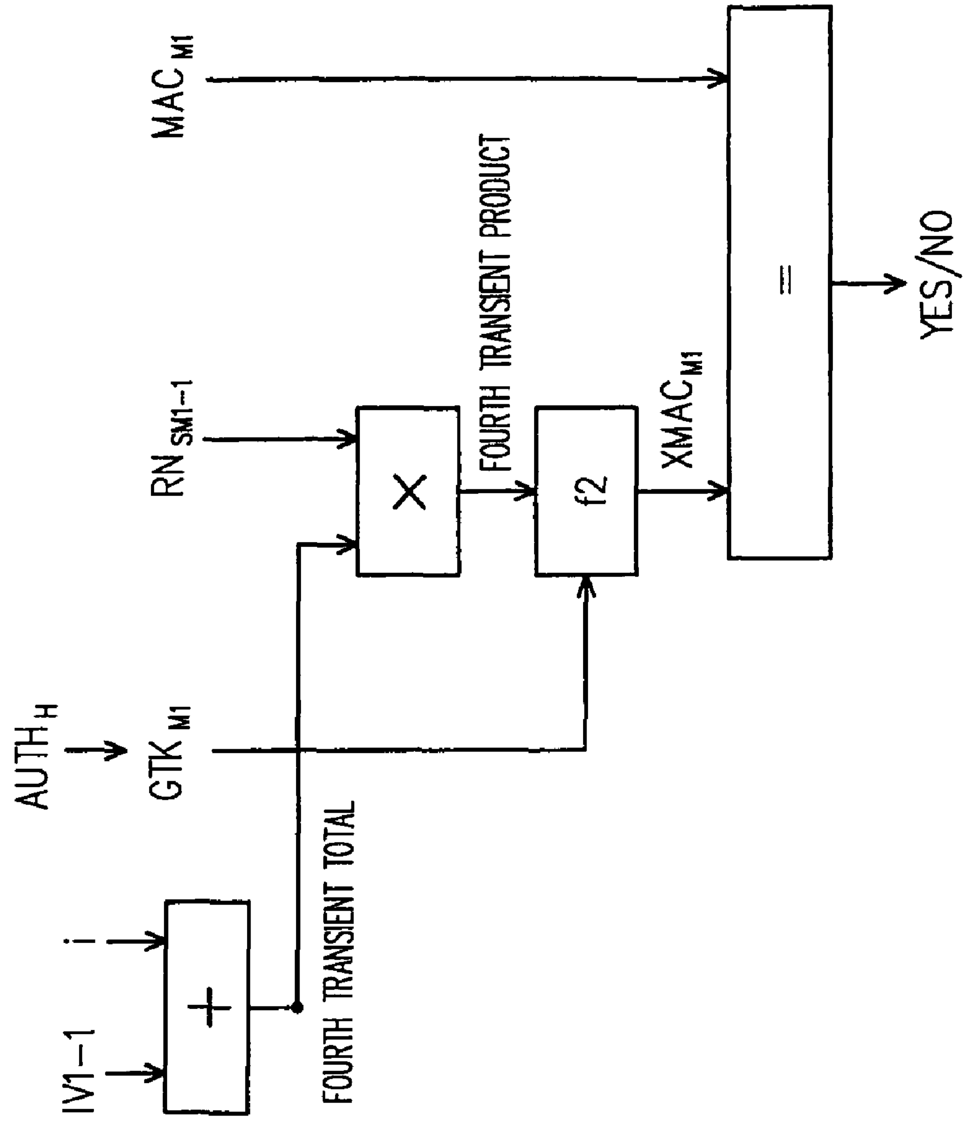

IV1-1
i
+
FOURTH TRANSIENT TOTAL
AUTH_H
GTK_M1
RN_SM1-1
×
FOURTH TRANSIENT PRODUCT
f2
XMAC_M1
MAC_M1
=
YES/NO

FIG. 15

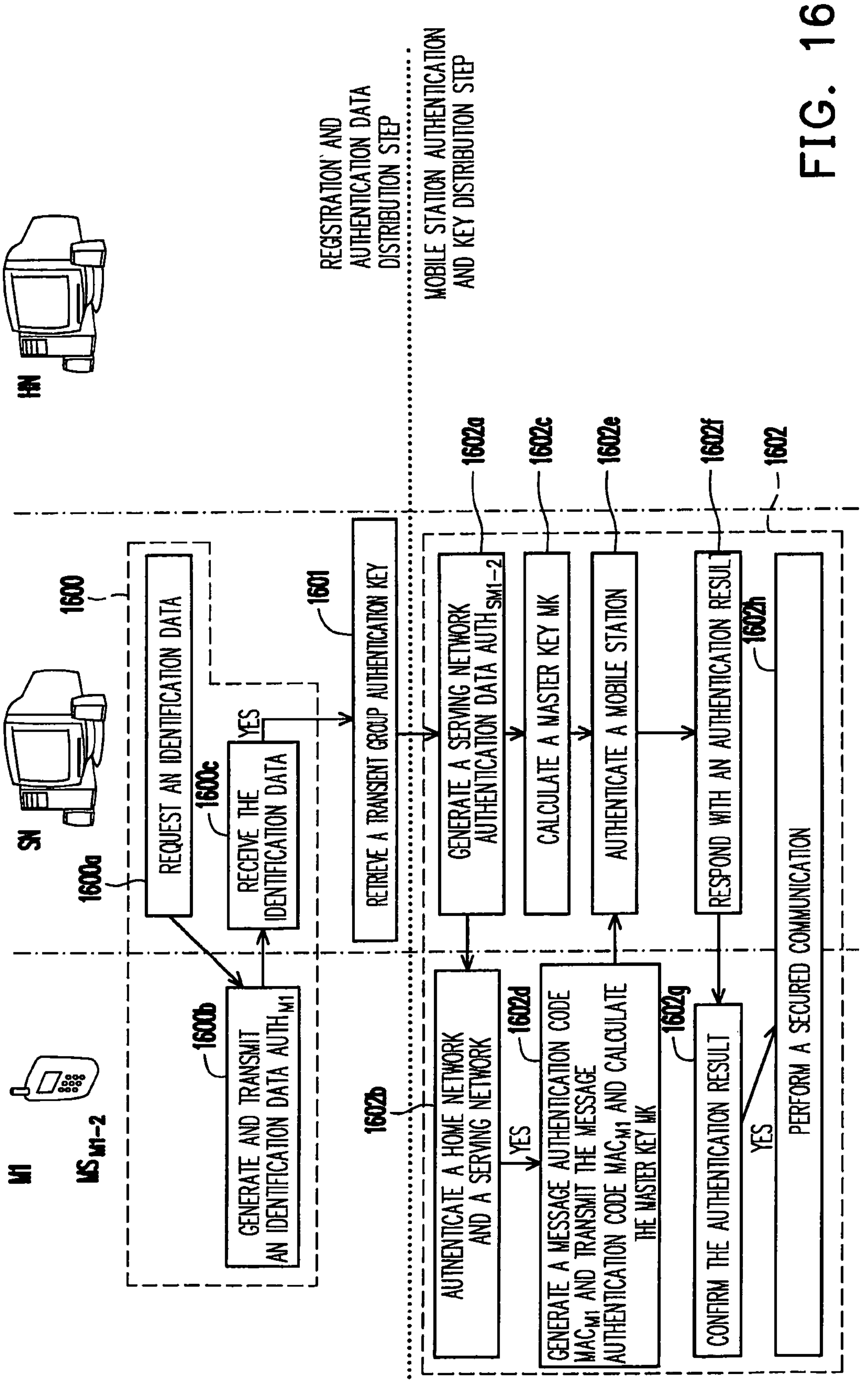

HN
SN
M1
MS$_{M1-2}$
REGISTRATION AND AUTHENTICATION DATA DISTRIBUTION STEP
MOBILE STATION AUTHENTICATION AND KEY DISTRIBUTION STEP
1600
1600a
REQUEST AN IDENTIFICATION DATA
1600b
GENERATE AND TRANSMIT AN IDENTIFICATION DATA AUTH$_{M1}$
1600c
RECEIVE THE IDENTIFICATION DATA
YES
1601
RETRIEVE A TRANSIENT GROUP AUTHENTICATION KEY
1602a
GENERATE A SERVING NETWORK AUTHENTICATION DATA AUTH$_{SM1-2}$
1602b
AUTNENTICATE A HOME NETWORK AND A SERVING NETWORK
YES
1602c
CALCULATE A MASTER KEY MK
1602d
GENERATE A MESSAGE AUTHENTICATION CODE MAC$_{M1}$ AND TRANSMIT THE MESSAGE AUTHENTICATION CODE MAC$_{M1}$ AND CALCULATE THE MASTER KEY MK
1602e
AUTHENTICATE A MOBILE STATION
1602f
RESPOND WITH AN AUTHENTICATION RESUL
1602g
CONFIRM THE AUTHENTICATION RESULT
YES
1602h
PERFORM A SECURED COMMUNICATION
1602

FIG. 16

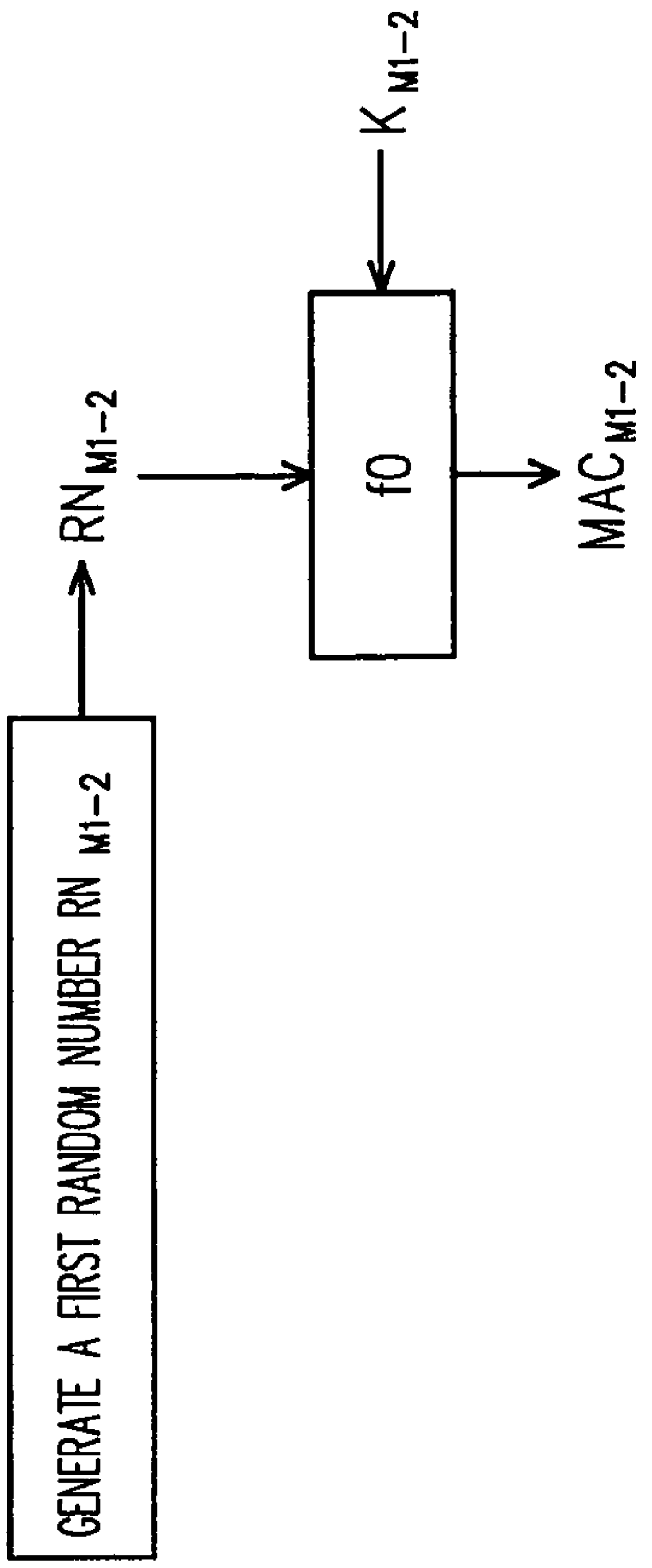


FIG. 17

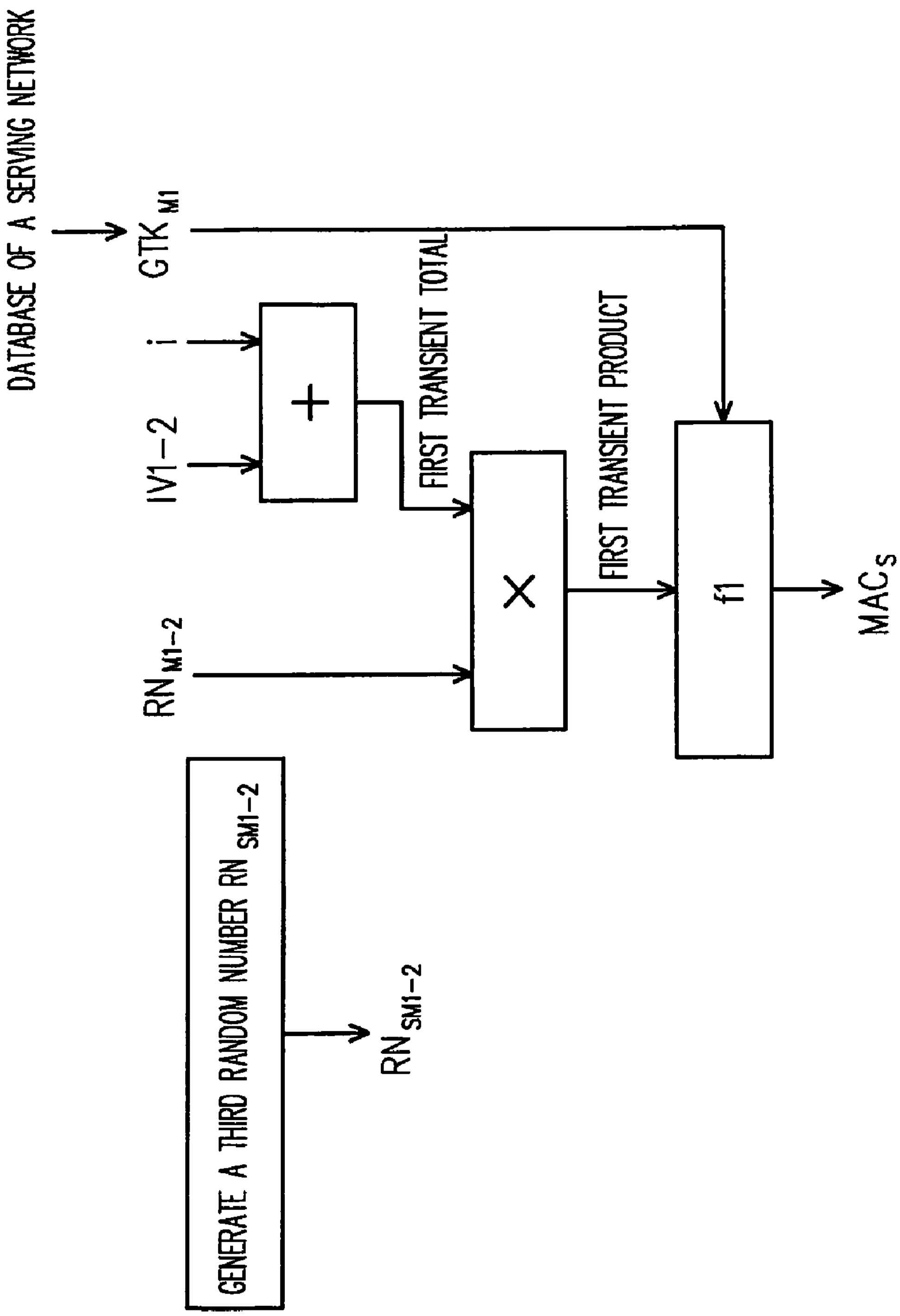

DATABASE OF A SERVING NETWORK
GTK$_{M1}$
i
IV1−2
RN$_{M1-2}$
+
FIRST TRANSIENT TOTAL
×
FIRST TRANSIENT PRODUCT
f1
MAC$_S$
GENERATE A THIRD RANDOM NUMBER RN$_{SM1-2}$
RN$_{SM1-2}$

FIG. 18

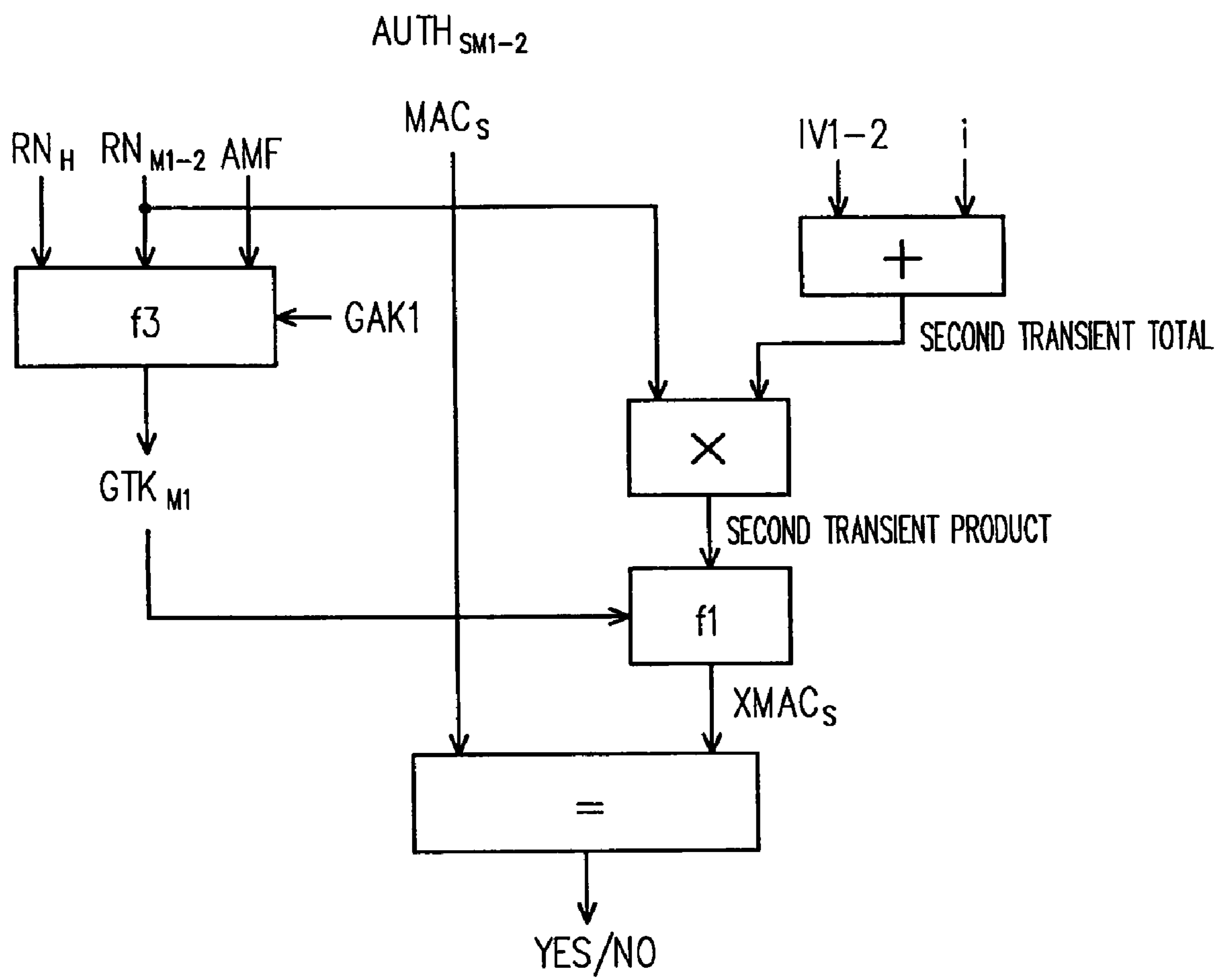

AUTH$_{SM1-2}$
MAC$_S$
RN$_H$
RN$_{M1-2}$
AMF
f3
GAK1
GTK$_{M1}$
IV1−2
i
+
SECOND TRANSIENT TOTAL
×
SECOND TRANSIENT PRODUCT
f1
XMAC$_S$
=
YES/NO

FIG. 19

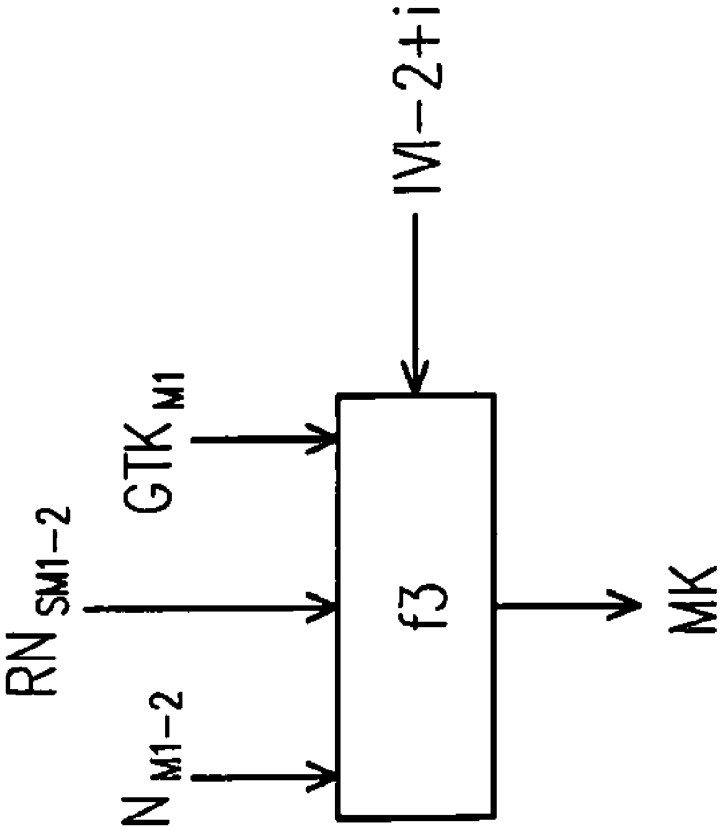


FIG. 20

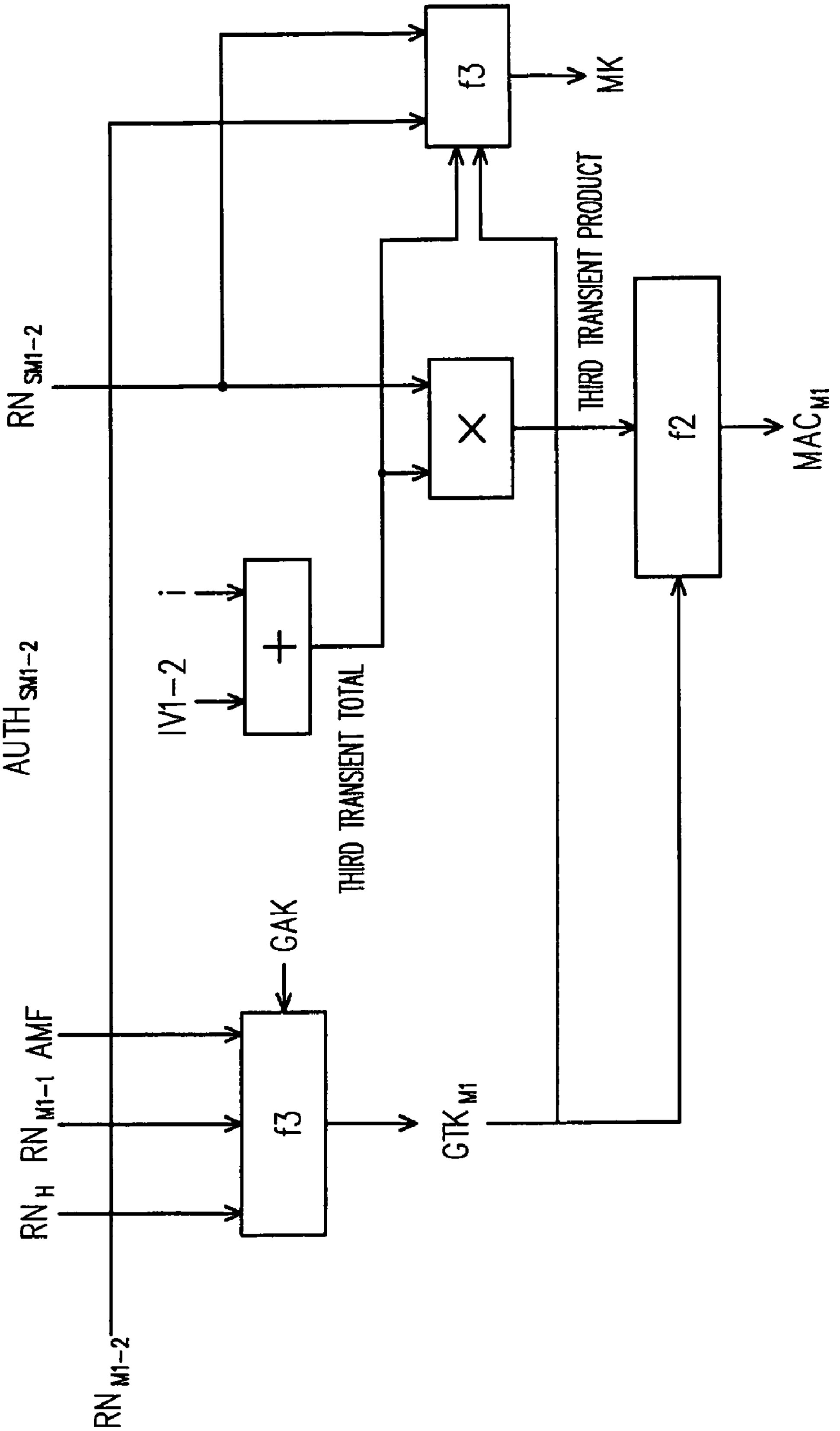

RN_SM1-2
AUTH_SM1-2
RN_M1-2
RN_H
RN_M1-1
AMF
GAK
f3
GTK_M1
IV1-2
i
+
THIRD TRANSIENT TOTAL
×
THIRD TRANSIENT PRODUCT
f3
MK
f2
MAC_M1

FIG. 21

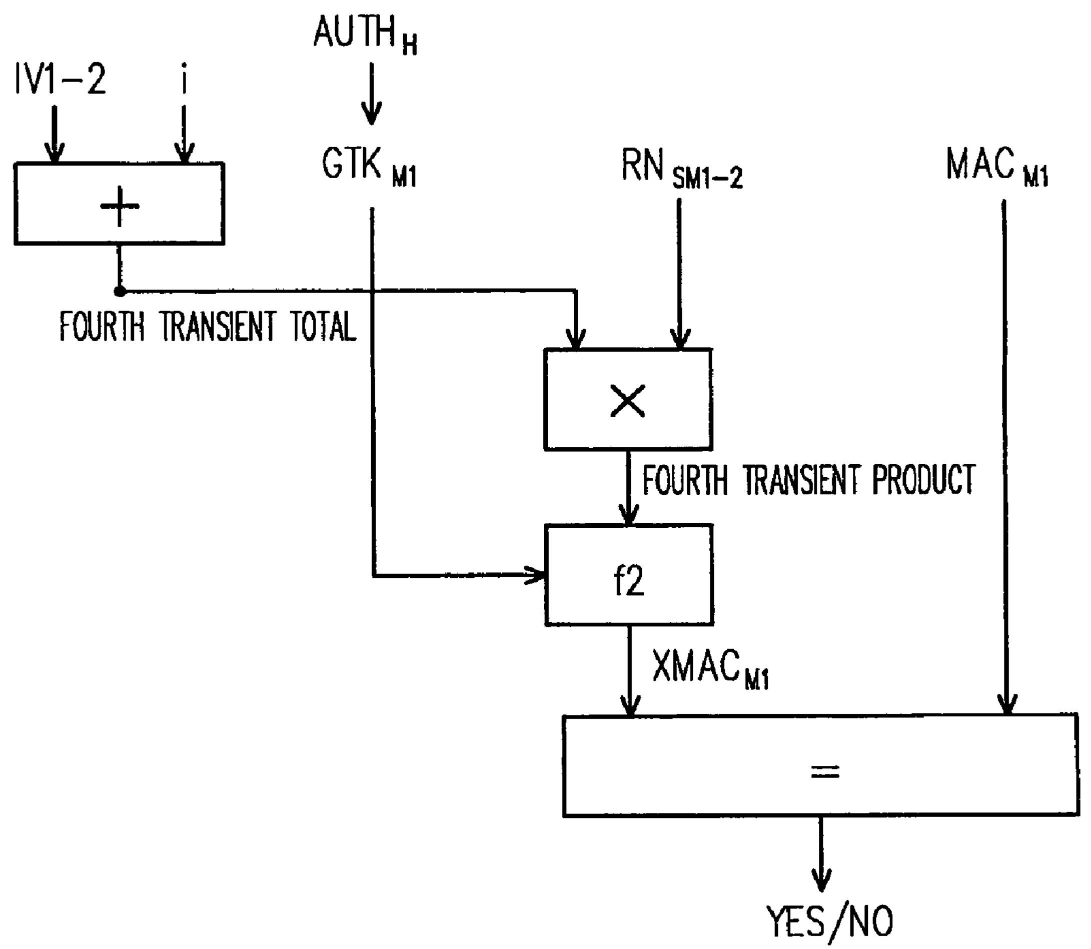

$AUTH_H$
$IV1-2$
i
GTK_{M1}
RN_{SM1-2}
MAC_{M1}
+
FOURTH TRANSIENT TOTAL
×
FOURTH TRANSIENT PRODUCT
f2
$XMAC_{M1}$
=
YES/NO

FIG. 22

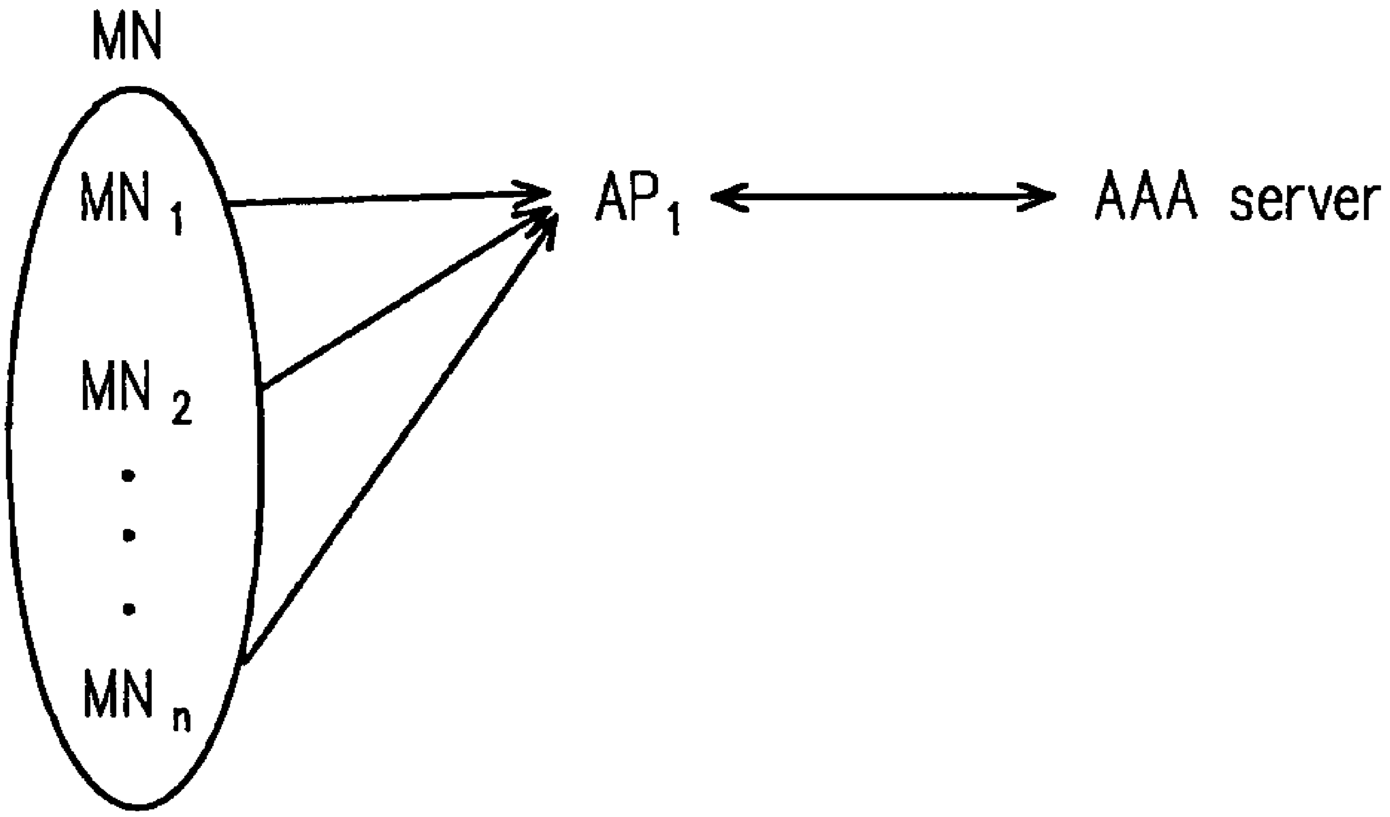


FIG. 23

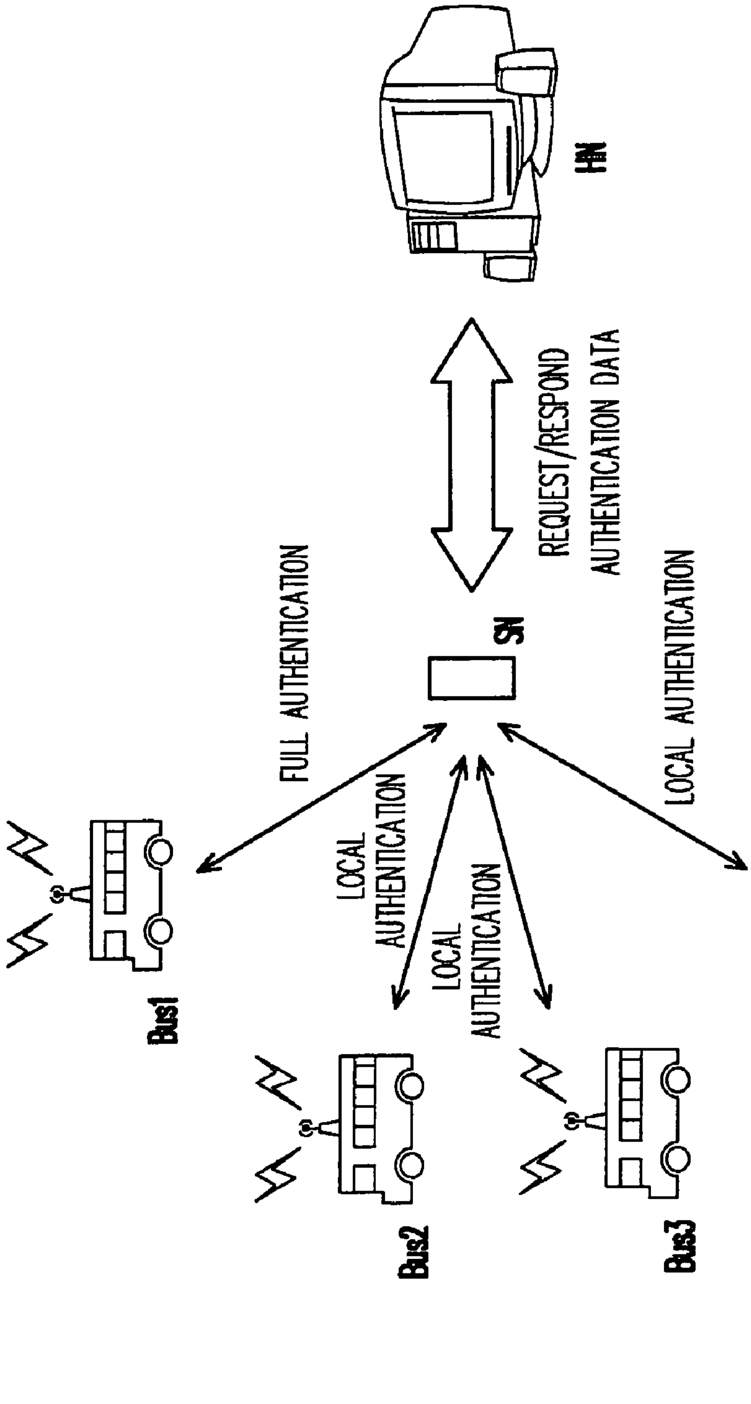

HN
REQUEST/RESPOND
AUTHENTICATION DATA
SN
FULL AUTHENTICATION
LOCAL AUTHENTICATION
LOCAL AUTHENTICATION
LOCAL AUTHENTICATION
Bus1
Bus2
Bus3
Bus4

FIG. 24

GROUP AUTHENTICATION METHOD

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the priority benefit of Taiwan application serial no. 96131436, filed on Aug. 24, 2007. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of this specification.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to an authentication method, in particular, to a group authentication method.

2. Description of Related Art

Along with the emergences of different killer applications in wireless networks, various real-time communication services have also been developed. However, since data packets in a wireless network are mostly transmitted through air, the wireless network offers lower security level compared to a wired network. Besides, the bandwidth and speed of a wireless network are also much lower than those of a wired network. Together with the delay caused by authentication message relaying while roaming in different domains, the handoff time in the wireless network is considerably increased. Accordingly, how to shorten the handoff time in data transmission without damaging the security has become the focus of wireless network development.

Current authentication and key agreement (AKA) mechanisms for wireless networks are mostly designed for working with single mobile station. Taking the universal mobile telecommunications system (UMTS) AKA protocol as an example, when a mobile station roams, a local network service provider (i.e. a serving network) requests the authentication vectors of the mobile station from a home network of the mobile station, so that the serving network and the mobile station can perform authentication and master key agreement accordingly.

To meet the requirements of different wireless networks, an AKA mechanism usually includes two procedures: a. registration and authentication data distribution; and b. user authentication and key agreement. First, the serving network requests the related authentication data of the mobile station from a home network of the mobile station. Then, the serving network and the mobile station generate a series of challenge messages and response messages, and generate a master session key which can be used after the authentication succeeds.

FIG. **1** is a flowchart of the UMTS AKA authentication method adaptable to a communication system. Referring to FIG. **1**, the communication system includes a mobile station MS**1**, a serving network SN, and a home network HN. The mobile station MS**1** and the home network HN have a pre-distributed secret key K (referring to FIG. **2**), and the home network HN and the mobile station MS**1** have a message authentication code (MAC) generation function f**1**, an authentication message generation function f**2**, a cipher key generation function f**3**, and a integrity key generation function f**4**. The home network HN further has an authentication key generation function f**5** and a plurality of authentication management fields (AMFs). The serving network SN and the home network HN respectively have a database for recording the required data during the authentication process. When the mobile station MS**1** roamings, the mobile station MS**1** has to perform a full authentication with the serving network SN, wherein the full authentication includes an identification step **100**, an authentication vector obtaining step **101**, and a user authentication and key distribution step **102**. The identification step **100** and the authentication vector obtaining step **101** belong to aforementioned registration and authentication data distribution procedure, and the user authentication and key distribution step **102** belongs to abovementioned user authentication and key agreement procedure.

The UMTS AKA authentication method includes the following steps while it is applied to a communication system. First of all, the identification step **100** is executed as follows. In step **100***a*, the serving network SN requests the mobile station MS**1** for an identification data. In step **100***b*, the mobile station MS**1** generates the identification data and sends the identification data to the serving network SN. The identification data contains an ID of the mobile station MS**1** so that the serving network SN can identify the mobile station MS**1** based on the ID. In step **100***c*, the serving network SN receives the identification data from the mobile station MS**1** and identifies the mobile station MS**1**, and an exclusive information field of the mobile station MS**1** is established in the database of the serving network SN based on the identification data.

After that, the authentication vector obtaining step **101** is executed. In step **101***a*, the serving network SN sends the identification data to the home network HN and requests the authentication vectors of the mobile station MS**1** from the home network HN. In step **101***b*, the home network HN receives the identification data and generates a plurality of authentication vectors AV(**1**), AV(**2**), . . . , AV(n) based on the identification data, and then the home network HN sends the authentication vectors AV(**1**)~AV(n) to the serving network SN. In step **101***c*, the authentication vectors AV(**1**)~AV(n) are stored in the database of the serving network SN.

Finally, the user authentication and key distribution step **102** is executed in following steps to complete the authentication of the mobile station MS**1**. In step **102***a*, the serving network SN selects an authentication vector AV(i) from the database thereof and sends RAND(i) and AUTN(i) in the authentication vector AV(i) to the mobile station MS**1** (will be described below with reference to FIG. **2**). In step **102***b*, the mobile station MS**1** authenticates the home network HN based on RAND(i) and AUTN(i) in the authentication vector AV(i) (will be described below with reference to FIG. **3**). In step **102***c*, the mobile station MS**1** generates a mobile station authentication data RES(i) based on RAND(i) in the authentication vector AV(i) and the pre-distributed secret key K and sends the mobile station authentication data RES(i) to the serving network SN if the mobile station MS**1** successfully authenticates the home network HN. In step **102***d*, the serving network SN receives the mobile station authentication data RES(i), and the serving network SN authenticates the mobile station MS**1** based on the mobile station authentication data RES(i) and generates an authentication result. In step **102***e*, the serving network SN sends the authentication result to the mobile station MS**1**. In step **102***f*, the mobile station MS**1** receives and confirms the authentication result. In step **102***g*, if the authentication result shows that the serving network SN has successfully authenticated the mobile station MS**1**, the serving network SN selects a cipher key CK(i) and a integrity key IK(i) to secure the later communication, and the mobile station MS**1** inputs RAND(i) and the pre-distributed secret key K into the cipher key generation function f**3** and the integrity key generation function f**4** to calculate the cipher key CK(i) and the integrity key IK(i) correspondingly.

FIG. **2** is a diagram illustrating how the authentication vector AV(i) is generated in the UMTS AKA authentication method. Referring to FIG. **2**, the home network HN searches for the secret key K of the mobile station MS1 from the database of the home network HN based on the ID of mobile station MS1 in the identification data (step **200**), and generates a sequence number SQN(i) (step **201**) and a random number RAND(i) (step **202**). The home network HN inputs the random number RAND(i), the secret key K, the sequence number SQN(i), and a plurality of AMFs AMF into the MAC generation function f**1** to generate a MAC MAC(i); the home network HN inputs the random number RAND(i) and the secret key K into the authentication message generation function f**2** to generate an authentication message for eXpexted RESponse XRES(i); the home network HN inputs the random number RAND(i) and the secret key K into the cipher key generation function f**3** to generate the cipher key CK(i); the home network HN inputs the random number RAND(i) and the secret key K into the integrity key generation function f**4** to generate the integrity key IK(i); the home network HN inputs the random number RAND(i) and the secret key K into the anonymity key generation function f**5** to generate an anonymity key AK(i); and the home network HN further performs an XOR calculation on the sequence number SQN(i) and the anonymity key AK(i) to obtain a result SQN(i)⊕AK (i) (step **203**) so that the serving network SN will be unaware about the real sequence number SQN(i). The home network HN combines the result SQN(i)⊕AK(i), the AMFs AMF, and the MAC MAC(i) into an authentication token AUTN(i) (i.e. AUTN(i)={SQN(i)⊕AK(i)||AMF||MAC(i)}, wherein || represents the combination operator, for example, {110||101}={110101}). Next, the home network HN combines the random number RAND(i), the authentication message for eXpected RESponse XRES(i), the cipher key CK(i), the integrity key IK(i), and the authentication token AUTN(i) into the authentication vector AV(i) (i.e. AV(i)={RAND(i) |XRES(i)|CK(i)|IK(i)|AUTN(i)}).

FIG. **3** is a diagram illustrating how the mobile station MS1 authenticates the home network HN and generates the mobile station authentication data RES(i) based on RAND(i) and AUTN(i) sent by the serving network SN. First, the mobile station MS1 inputs the random number RAND(i) and the pre-distributed secret key K of the mobile station MS1 into the anonymity key generation function f**5** to generate the anonymity key AK(i). Next, the mobile station MS1 performs an XOR calculation on the result of SQN(i)⊕AK(i) in AUTN (i) with the anonymity key AK(i) generated by the mobile station MS1 to acquire the sequence number SQN(i). The mobile station MS1 inputs the AMFs AMF, the sequence number SQN(i) derived by the mobile station MS1, and the secret key K of the mobile station MS1 into the MAC generation function f**1** to generate an eXpected MAC XMAC(i). The mobile station MS1 compares the MAC XMAC(i) with the MAC MAC(i) in the AUTN(i) received from the serving network SN to authenticate the home network HN. If the result of comparison shows match which means that the mobile station MS1 successfully authenticates the home network HN, the mobile station MS1 inputs the random number RAND(i) received from the serving network SN and the secret key K of the mobile station MS1 into the authentication message generation function f**2** to generate the mobile station authentication data RES(i). Meanwhile, the mobile station MS1 also inputs the secret key K of the mobile station MS1 and the random number RAND(i) received from the serving network SN into the cipher key generation function f**3** and the integrity key generation function f**4** to generate the cipher key CK(i) and the integrity key IK(i) which will be used to provide security for subsequent communication. The mobile station MS1 sends the mobile station authentication data RES(i) to the serving network SN. The serving network SN then compares the mobile station authentication data RES(i) with the authentication message expected RESponse XRES(i) in order to authenticate the mobile station MS1.

Either the mobile station MS1 fails to authenticate the home network HN or the serving network SN fails to authenticate the mobile station MS1, the communication system terminates the entire communication or requests re-authentication. For the convenience of description, FIG. **1** illustrates only the situation that both the authentications succeed. When a group of mobile stations perform hand off together, the UMTS AKA generates individual authentication data for each mobile stations which causes the signaling overhead between the serving network SN and the home network HN since the authentication data request and response messages are repeated and transmitted for all mobile stations in the same group.

In the UMTS AKA authentication method described above, the database of the serving network SN requires a large storage space for storing the authentication vectors AV(**1**)~AV(n) that support at most n authentications. Besides, in the UMTS AKA authentication method, the home network HN cannot authenticate the mobile station MS1, namely, the home network HN cannot determine whether the mobile station MS1, who requests the authentication vectors AV(**1**)~AV (n) from the home network HN through the serving network SN, is legitimate or not.

FIG. **4** illustrates an authentication flow when a mobile station MS1 hands off for the first time based on a UMTS X-AKA authentication method disclosed in the article "Authentication and Key Agreement Protocol for UMTS with Low Bandwidth Consumption" published in IEEE AINA 2005. The UMTS X-AKA authentication method is suitable for a communication system which includes a mobile station MS1, a serving network SN, and a home network HN. The mobile station MS1 and the home network HN both have a pre-distributed secret key. The serving network SN and the home network HN have a database respectively. When the mobile station MS1 hands off for the first time, the full authentication procedure is executed. The full authentication includes an identification step **400**, an authentication data obtaining step **401**, and a user authentication and key distribution step **402**, where the identification step **400** and the authentication data obtaining step **401** belong to the aforementioned registration and authentication data distribution procedure, and the user authentication and key distribution step **402** belongs to the abovementioned user authentication and key agreement procedure.

The UMTS X-AKA authentication method includes the following steps while it is applied to a communication system. First, in step **400***a*, the serving network SN sends an identification data request to the mobile station MS1. In step **400***b*, the mobile station MS1 generates the identification data and a timestamp t and then sends the identification data and the timestamp t back to the serving network SN, where the identification data contains an ID of the mobile station MS1 so that the serving network SN can identify the mobile station MS1 based on the ID. In step **400***c*, the serving network SN receives the identification data from the mobile station MS1 and identifies the mobile station MS1 in the database of the serving network SN. If the authentication data of the mobile station MS1 is not recorded in the database, an exclusive information field for the mobile station MS1 is established in the database of the serving network SN based on the identification data and step **401** is then executed; if the authentication data and a temporary authentication key of the mobile station MS1 are recorded in the database, the serving network SN selects the authentication data and the temporary authentication key from the database, and step **501** as illustrated in FIG. **5** is executed consequently. In FIG. **4**, the next step is assumed to be step **401** (for the convenience of description, the mobile station MS**1** is assumed to hand off for the first time).

Next, the authentication data obtaining step **401** is executed in following steps. In step **401***a*, the serving network SN sends the identification data and the timestamp t to the home network HN and requests the authentication data of the mobile station MS**1** from the home network HN. In step **401***b*, the home network HN receives the identification data and the timestamp t and generates the authentication data (containing a temporary authentication key) based on the identification data and the timestamp t, and then the home network HN sends the authentication data to the serving network SN. In step **401***c*, the authentication data and the temporary authentication key are stored in the database of the serving network SN.

Finally, the user authentication and key distribution step **402** is executed by following the steps below to complete the full authentication of the mobile station MS**1**. In step **402***a*, the serving network SN generates a serving network authentication data and a random number and then sends the serving network authentication data and the random number to the mobile station MS**1**. In step **402***b*, the mobile station MS**1** authenticates the home network HN and the serving network SN based on the serving network authentication data and the random number. In step **402***c*, the mobile station MS**1** generates a mobile station authentication data based on a part of the serving network authentication data and the temporary authentication key generated by the mobile station MS**1**, and then sends the mobile station authentication data to the serving network SN if the mobile station MS**1** in step **402***b* successfully authenticates the serving network SN. In step **402***d*, after the serving network SN receives the mobile station authentication data, the serving network SN authenticates the mobile station MS**1** based on the mobile station authentication data and generates an authentication result. In step **402***e*, the serving network SN sends the authentication result to the mobile station MS**1**. In step **402***f*, the mobile station MS**1** receives and confirms the authentication result. In step **402***g*, if the authentication result shows that the serving network SN has successfully authenticated the mobile station MS**1**, the mobile station MS**1** and the serving network SN generate a master key respectively based on the temporary authentication key and the random number generated by the serving network SN to secure the later data transmission.

FIG. **5** illustrates an authentication flow based on the UMTS X-AKA authentication method for the subsequent authentication requests after the mobile station MS**1** hands off for the first time. This procedure includes an identification step **500** and a user authentication and key distribution step **501**, wherein the identification step **500** belongs to aforementioned registration and authentication data distribution procedure, and the user authentication and key distribution step **501** belongs to aforementioned user authentication and key agreement procedure. The serving network SN determines whether the authentication data and temporary authentication key of the mobile station MS**1** already existed in the database of the serving network SN. If the authentication data and temporary authentication key of the mobile station MS**1** have been stored in the database of the serving network SN, the serving network SN stops requesting the authentication data and temporary authentication key from the home network HN. The authentication data and temporary authentication key of the mobile station MS**1** can be found in the database of the serving network SN since it is not the first time that the mobile station MS**1** hands off.

First, the identification step **500** is executed as follows. In step **500***a*, the serving network SN sends an identification data request to the mobile station MS**1**. In step **500***b*, the mobile station MS**1** generates the identification data and a timestamp t and sends the identification data and the timestamp t to the serving network SN, where the identification data contains an ID of the mobile station MS**1** so that the serving network SN can identify the mobile station MS**1** based on the ID. In step **500***c*, the serving network SN receives the identification data generated by the mobile station MS**1** and identifies the mobile station MS**1**. The serving network SN searches for the authentication data and temporary authentication key of the mobile station MS**1** in the database of the serving network SN. If the authentication data and temporary authentication key of the mobile station MS**1** are not found in the database of the serving network SN, the authentication method takes the flow as illustrated in FIG. **4**. FIG. **5** illustrates the situation that the authentication data and temporary authentication key of the mobile station MS**1** have been stored in the database of the serving network SN, thus, the serving network SN can locate the authentication data and temporary authentication key of the mobile station MS**1** in the database.

After that, the user authentication and key distribution step **501** is executed in the following steps to complete the authentication of the mobile station MS**1**. In step **501***a*, the serving network SN generates a serving network authentication data and a random number and sends the serving network authentication data and the random number to the mobile station MS**1**. In step **501***b*, the mobile station MS**1** authenticates the serving network SN based on the serving network authentication data and the random number. In step **501***c*, the mobile station MS**1** generates a mobile station authentication data based on a part of the authentication data and the temporary authentication key generated previously by the mobile station MS**1** and sends the mobile station authentication data to the serving network SN if the mobile station MS**1** successfully authenticates the serving network SN. In step **501***d*, the serving network SN receives the mobile station authentication data, authenticates the mobile station MS**1** based on the mobile station authentication data, and generates an authentication result. In step **501***e*, the serving network SN sends the authentication result to the mobile station MS**1**. In step **501***f*, the mobile station MS**1** receives and confirms the authentication result. In step **501***g*, if the authentication result shows that the serving network SN has successfully authenticated the mobile station MS**1**, the mobile station MS**1** and the serving network SN respectively generate a master key based on the temporary authentication key and the random number to secure the subsequent data transmission.

Additionally, either the mobile station MS**1** fails to authentication the serving network SN or the home network HN or the serving network SN fails to authenticate the mobile station MS, the communication system terminates the entire communication or request re-authentication. For the convenience of description, FIG. **4** and FIG. **5** illustrate only the situation that both the authentications succeed.

According to the UMTS X-AKA authentication method, the home network HN generates a temporary authentication key for the serving network SN and authorizes the serving network SN to authenticate the mobile station MS**1**, so that the traffic load between the home network HN and the serving network SN can be reduced when the mobile station MS**1** requests for re-authenticated. Moreover, in the UMTS X-AKA authentication method, the storage space required by the database of the serving network SN is also reduced. However, in the UMTS X-AKA authentication method, the home network HN still cannot authenticate the mobile station MS**1**. When a group of mobile stations perform hand off together, the UMTS X-AKA generates individual authentication data for each mobile stations which causes the signaling overhead between the serving network SN and the home network HN since the authentication data request and response messages are repeated and transmitted for all mobile stations in the same group.

FIG. **6** is a flowchart of an authentication method disclosed in U.S. Pat. No. 6,711,400. The authentication method is adaptable to a communication system which includes a mobile station MS**1**, a serving network SN, and a home network HN. The mobile station MS**1** and the home network HN have a pre-distributed secret key, and the serving network SN and the home network HN respectively have a database. When the mobile station MS**1** hands off, the mobile station MS**1** has to perform a full authentication. The authentication method includes an identification step **600**, an authentication data obtaining step **601**, and a user authentication and key distribution step **602**, where the identification step **600** and the authentication data obtaining step **601** belong to the abovementioned registration and authentication data distribution procedure, and the user authentication and key distribution step **602** belongs to the abovementioned user authentication and key agreement procedure. In this authentication method, the full authentication refers to the execution of the authentication data obtaining step **601** and the user authentication and key distribution step **602**.

The authentication method includes following steps while it is applied to a communication system. First, the identification step **600** is executed in following steps. In step **600***a*, the mobile station MS**1** generates an identification data by using the pre-distributed secret key and a first random number. The mobile station MS**1** then sends the identification data and the first random number to the serving network SN, wherein the identification data contains an ID of the mobile station MS**1** so that the serving network can identity the mobile station MS**1** based on the ID. In step **600***b*, the serving network SN receives the identification data generated by the mobile station MS**1** and identifies the mobile station MS**1**. An exclusive information field of the mobile station MS**1** is established in the database of the serving network SN based on the identification data.

After that, the authentication data obtaining step **601** is executed in following steps. In step **601***a*, the serving network SN sends the identification data and the first random number to the home network HN and requests an authentication data of the mobile station MS**1** from the home network HN. In step **601***b*, the home network HN receives the identification data and the first random number and selects the secret key based on the identification data. In step **601***c*, the home network HN generates a second random number, and then the authentication data, a cipher key, and a comparison data based on the first random number, the second random number, and the secret key. The home network HN sends the authentication data, the cipher key, the comparison data, and the second random number to the serving network SN. In step **601***d*, after the serving network SN receives the authentication data, the cipher key, the comparison data, and the second random number, and the cipher key and the comparison data are stored in the database of the serving network SN.

Finally, the user authentication and key distribution step **602** is executed in following steps to complete the authentication of the mobile station MS**1**. In step **602***a*, the serving network SN sends the authentication data and the second random number from the database thereof to the mobile station MS**1**. In step **602***b*, the mobile station MS**1** authenticates the home network HN based on the authentication data. After the mobile station MS**1** successfully authenticates the home network HN, the mobile station MS**1** in step **602***c* generates a mobile station authentication data and a cipher key based on the pre-distributed secret key and the second random number and sends the mobile station authentication data to the serving network SN. In step **602***d*, the serving network SN receives the mobile station authentication data and authenticates the mobile station MS**1** based on the mobile station authentication data and the comparison data in the database and then generates an authentication result. In step **602***e*, the serving network SN sends the authentication result to the mobile station MS**1**. In step **602***f*, the mobile station MS**1** receives and confirms the authentication result. In step **602***g*, if the authentication result shows that the serving network SN has successfully authenticated the mobile station MS**1**, the mobile station MS**1** and the serving network SN calculate a master key to secure the subsequent communication.

Additionally, either the mobile station fails to authenticate the home network HN or the serving network SN or the serving network SN fails to authenticate the mobile station MS**1**, the communication system terminates the entire communication or requests re-authentication. For the convenience of description, FIG. **6** only illustrates the situation that both the authentications succeed.

According to the authentication method disclosed in U.S. Pat. No. 6,711,400, the mobile station MS**1** allocates a first random number to the home network HN to ensure the freshness of the authentication data. The serving network SN is used only for relaying the authentication data generated by the home network HN and for verifying the mobile station authentication data used for authenticating the mobile station MS**1**; the serving network SN is not responsible for generation any authentication data. However, in this authentication method, only one authentication data is generated every time and the generated authentication data can be used for exactly one mobile station just once. Thus, signalling overhead between the serving network SN and the home network HN is increased if the re-authentication is required or a group of mobile stations perform authentication procedures together, namely, both the traffic load between the serving network SN and the home network HN and the bandwidth wasted are increased.

However, the concept of group in wireless networks has been evolving along with the development of group communication services. Mobile stations belonging to the same home network HN often communicate in a form of group. Such a group is likely to migrate somewhere together. That is, mobile stations of an HN visit the same serving network SN or move along the same route, e.g., a tourist group from the same city or country traveling from one place to another, students having a field trip, or even mobile routers on a public transportation system. However, there is no group authentication mechanism provided in existing networks so that those roaming mobile stations of the same group have to be authenticated individually. In addition, the authentication requests and responses sent by the serving network SN and the home network HN increase the traffic load of the network, the signalling overhead, and accordingly the bandwidth between the serving network SN and the home network HN.

Foregoing authentication methods are all designed for the authentication of a single mobile station. Thus, when these authentication methods are applied to group communication, they confront the same problem: the serving network SN has to relay an authentication request regarding each mobile station to the same home network HN and then receive the authentication data of each mobile station from the home network HN at the same time. This patent proposes a new idea about shared group data for authentication. the group authentication key pre-distribution is achieved through group authentication data sharing, and on the other hand, the bandwidth used for data transmission between the serving network and the home network is reduced by adopting local authentications.

SUMMARY OF THE INVENTION

The present invention relates to a group authentication method adaptable to any communication system which requires remote authentication. The communication system includes a user group, a serving network, and a home network. The user group includes at least one mobile station. The serving network has a database for recording group lists and group authentication data received from the home network. The home network pre-distributes a group authentication key and a mobile station authentication key to the mobile station and itself. Besides, the home network has a database for recording the group lists generated by the home network. In the group authentication method, the serving network identifies the mobile station. in order to determine whether the home network has to provide an authentication data or not. If the authentication data (including the group list) of the mobile station has been stored in the database of the serving network, the serving network can directly perform a local authentication to the mobile station without informing the home network. If the authentication data of the mobile station does not exist in the database of the serving network, the serving network has to obtain the authentication data from the home network in order to perform a full authentication with the mobile station.

The mobile station and the home network have a group authentication key and a mobile station authentication key. The home network has a group list. The mobile station has a mobile station ID, a group number, and an initial value. The serving network has a database for recording the group list received from the home network. The group authentication method includes the following steps. In step (a), the mobile station generates the identification data which contains the first message authentication code (MAC) and the mobile station ID. In step (b), the identification data is transmitted to the serving network. In step (c), the serving network searches the mobile station ID in the group list in the database. If the mobile station ID is not recorded in the group list in the database, the identification data is transmitted to the home network; the home network generates the second MAC based on the identification data and then compares it with the first MAC; if the first MAC is equal to the second MAC, the home network successfully authenticates the mobile station; the home network generates a group transient key (GTK) based on the group authentication key; the home network transmit the group list and the group authentication data including GTK to the serving network; the serving network records the group list and the group authentication data in the database of the serving network. After the mobile station ID is stored in the group list in the database, the group authentication data can be found and retrieved from the database of the serving network based on the mobile station ID. In step (d), the serving network generates third MAC based on the group authentication data. In step (e), the serving network transmits a serving network authentication data which contains the third MAC to the mobile station. In step (f), the mobile station generates a GTK based on the serving network authentication data, and a fourth MAC based on the GTK just generated. In step (g), the mobile station compares the third MAC with the fourth MAC. If the third MAC is equal to the fourth MAC, the mobile station successfully authenticates the serving network and the home network. In step (h), the serving network calculates a master key based on the group authentication data. In step (i), the mobile station generates the master key and a fifth MAC based on the serving network authentication data and the GTK. In step (j), the fifth MAC is transmitted to the serving network. In step (k), the serving network generates a sixth MAC based on the group authentication data. In step (l), the serving network compares the fifth MAC with the sixth MAC. If the fifth MAC is equal to the sixth MAC, the serving network successfully authenticates the mobile station. In step (m), the data transmitted between the serving network and the mobile station is protected by the master key so that a secure communication between the serving network and the mobile station is ensured.

As described above, this invention provides a group authentication method based on a group authentication key, i.e. all the mobile stations in the same group share a group authentication key. When a mobile station in the group roams to a foreign serving network for the first time, a full authentication is required. The serving network obtains the authentication data of the mobile station and a GTK from a home network of the mobile station. Subsequently, all the other mobile stations in the same group can use this GTK for authentication directly. If the serving network tries to authenticate another mobile station of the same group, local authentication can be performed by using the GTK stored in the database of the serving network without requesting the authentication data of the mobile station from the home network again. Accordingly, in this invention, group authentication key can be pre-distributed without extra message exchange. Moreover, handoff delay caused by authentications can be reduced considerably by local authentication.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

FIG. **1** is a flowchart of an UMTS AKA authentication method.

FIG. **2** illustrates how to generate an authentication vector AV(i) in the UMTS AKA authentication method.

FIG. **3** illustrates how a mobile station MS**1** authenticates a home network HN and generates a mobile station authentication data RES(i) based on Rand(i) and AUTN(i) sent from the serving network.

FIG. **4** illustrates an authentication flow when a mobile station MS**1** hands off for the first time based on a UMTS X-AKA authentication method.

FIG. **5** illustrates an authentication flow after the mobile station MS**1** hands off for the first time based on the UMTS X-AKA authentication method.

FIG. **6** is a flowchart of an authentication method disclosed in U.S. Pat. No. 6,711,400.

FIG. **7** is a flowchart of a group authentication method according to an exemplary embodiment of the present invention.

FIG. **8** illustrates a method for generating a message authentication code (MAC) $\mathrm{MAC}_{M1\text{-}1}$ in an identification data AUTH_{M1} provided by the mobile station $\mathrm{MS}_{M1\text{-}1}$ in step **700*b*** illustrated in FIG. **7**.

FIG. **9** illustrates how a home network HN authenticates a mobile station MS$_{M1\text{-}1}$ based on the identification data AUTH$_{M1}$ in step **701***b* illustrated in FIG. **7**.

FIG. **10** illustrates how the home network HN generates a group authentication data AUTH$_{H}$ in step **701***c* illustrated in FIG. **7**.

FIG. **11** illustrates a method for generating a serving network authentication data AUTH$_{SM1\text{-}1}$ in step **702***a* illustrated in FIG. **7**.

FIG. **12** illustrates how the mobile station MS$_{M1\text{-}1}$ authenticates a serving network SN in step **702***b* illustrated in FIG. **7**.

FIG. **13** illustrates a method for calculating a master key MK in step **702***c* illustrated in FIG. **7**.

FIG. **14** illustrates a method for calculating the master key MK and generating a fifth MAC MAC$_{M1}$ in step **702***d* illustrated in FIG. **7**.

FIG. **15** illustrates a method for generating an authentication result in step **702***e* illustrated in FIG. **7**.

FIG. **16** is a flowchart of a group authentication method according to an exemplary embodiment of the present invention.

FIG. **17** illustrates a method for generating an identification data AUTH$_{M1}$ in step **1600***b* illustrated in FIG. **16**.

FIG. **18** illustrates a method for generating a serving network authentication data AUTH$_{SM1\text{-}2}$ in step **1602***a* illustrated in FIG. **16**.

FIG. **19** illustrates how a mobile station MS$_{M1\text{-}2}$ authenticates a serving network SN in step **1602***b* illustrated in FIG. **16**.

FIG. **20** illustrates a method for calculating a master key MK in step **1602***c* illustrated in FIG. **16**.

FIG. **21** illustrates a method for calculating the master key MK and generating a fifth MAC MAC$_{M1}$ in step **1602***d* illustrated in FIG. **16**.

FIG. **22** illustrates a method for generating an authentication result in step **1602***e* illustrated in FIG. **16**.

FIG. **23** illustrates an application of a group authentication method provided by the present invention in an 802.11 network.

FIG. **24** illustrates an application of a group authentication method provided by the present invention for mobile routers.

DESCRIPTION OF THE EMBODIMENTS

Examples illustrated in the accompanying drawings of reference will now be made in detail to the present preferred embodiments of the invention. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

Based on the concept of group communication, users living in the same community, working with the same company, or taking buses on the same route can all be considered as a group, and the members in the same group tend to roam to the same place and perform authentication. Accordingly, the present invention proposes a concept and an infrastructure of group authentication to allow the mobile stations in the same group to share a group authentication data to enhance the authentication efficiency when a group of mobile stations hand off.

FIG. **7** is a flowchart of a group authentication method according to an exemplary embodiment of the present invention, in which a mobile station hands off for the first time among all the mobile stations in the same group.

The group authentication method is adaptable to a communication system which includes a mobile station group M**1**, a serving network SN, and a home network HN. The mobile station group M**1** includes mobile stations MS$_{M1\text{-}1}$ and MS$_{M1\text{-}2}$. The home network HN allocates the mobile stations MS$_{M1\text{-}1}$ and MS$_{M1\text{-}2}$ to the mobile station group M**1** before the communication system starts to transmit data. Besides, the home network HN distributes a mobile station authentication key and a group authentication key to the mobile stations MS$_{M1\text{-}1}$ and MS$_{M1\text{-}2}$ and the home network HN (i.e. the mobile stations MS$_{M1\text{-}1}$ and MS$_{M1\text{-}2}$ and the home network HN already have respectively a mobile station authentication key and a group authentication key, and the mobile station authentication keys for MS$_{M1\text{-}1}$ and MS$_{M1\text{-}2}$ are different). The home network HN resets the group authentication key when new mobile stations join or the original mobile stations leave the mobile station group M**1**. The home network HN and the serving network SN respectively have a database for storing group lists, group authentication data AUTH$_{H}$ generated by the home network, and identification data AUTH$_{M1}$ generated by the mobile stations.

As shown in the table below, the group list records a group number, a group authentication key, a mobile station ID with an initial value exclusive to each member, and other group related information, such as billing pattern etc. The group list table is indexed by the Group Number. The mobile station ID and initial value for MS$_{M1\text{-}1}$ are MS**1-1** and IV**1-1**; for MS$_{M1\text{-}2}$ IV**1-2** and MS**1-2**.

Group Number	Mobile Station ID	Initial Value	Group Related Information
G1	MS1-1	IV1-1	. . .
	MS1-2	IV1-2	. . .
	. . .	. . .	. . .
. . .	. . .	. . .	. . .

The generation and distribution of the group authentication key can be referred to "An Authenticated Group Key Agreement for Wireless Networks" (by Chik How Tan and Joseph Chee Ming Teo) published in *Wireless Communications and Networking Conference*, Vol. 4, 2005, pp. 2100-2105 and "Key Management for Multicast: Issues and Architectures" (by D. Wallner, F. Harder and R. Agee) published in *RFC*2626, June 1999. The group authentication keys for different groups are recorded and indexed by the corresponding group number in a key table stored only in the home network. The initial value IVi-j (wherein represents the ith group, j represents the ith mobile station) has too many bits to be speculated or repeated, so that the mobile stations in every group can have different initial values IVi-j. With this initial value IVi-j, a mobile station and a serving network can be synchronized in subsequent authentication procedure.

Referring to FIG. **7**, the home network HN and the mobile station MS$_{M1\text{-}1}$ have a mobile station authentication message generation function f**0**, a serving network authentication message generation function f**1**, a group authentication message generation function f**2**, and a key generation function f**3**. In addition, the home network HN has a plurality of authentication management fields (AMFs) AMF. When the mobile station MS$_{M1\text{-}1}$ hands off for the first time among all the mobile stations in the group M**1**, the mobile station MS$_{M1\text{-}1}$ has to perform a full authentication with the serving network SN. Here the group authentication method provided by the present invention includes an identification step **700**, a home network authentication step **701**, and a mobile station authentication and key distribution step **702**. The identification step **700** and the home network authentication step **701** belong to the aforementioned registration and authentication data distribution procedure, and the mobile station authentication and key distribution step **702** belongs to the aforementioned user authentication and key agreement procedure.

In the present invention, a full authentication action consists of the execution of the home network authentication step **701** and the mobile station authentication and key distribution step **702**. As the name of full authentication implies, the serving network SN authenticates the mobile station $MS_{M1\text{-}1}$ and the mobile station $MS_{M1\text{-}1}$ also authenticates the serving network SN. Besides, the home network HN authenticates the mobile station $MS_{M1\text{-}1}$ and the mobile station $MS_{M1\text{-}1}$ also authenticates the home network HN.

Following steps are executed when the group authentication method is applied to a communication system. First, the identification step **700** includes steps **700**a~**700**c. In step **700**a, the serving network SN requests an identification data from the mobile station $MS_{M1\text{-}1}$. In step **700**b, the mobile station $MS_{M1\text{-}1}$ generates the identification data $AUTH_{M1}$ and sends the identification data $AUTH_{M1}$ containing the mobile station ID to the serving network SN so that the serving network SN can identify the mobile station $MS_{M1\text{-}1}$ based on the mobile station ID MS**1**-**1**.

Next, in step **700**c, the serving network SN receives the identification data $AUTH_{M1}$ generated by the mobile station MS**1** and identifies the mobile station $MS_{M1\text{-}1}$. The serving network SN determines whether the mobile station ID MS**1**-**1** has been recorded in the group list in the database thereof. Since the mobile station $MS_{M1\text{-}1}$ is the first mobile station in the group M**1** who enters the serving network SN, the mobile station ID MS**1**-**1** does not exist in the database of the serving network SN. Thus, the home network authentication step **701** is then executed. The next step may vary if the mobile station ID can be found in the group list stored in the database of the serving network SN, and which will be described below with reference to step **1601** illustrated in FIG. **16**.

The home network authentication step **701** further includes steps **701**a~**701**d. In step **701**a, the serving network SN sends the identification data $AUTH_{M1}$ to the home network HN and requests the group list and the group authentication data $AUTH_H$ of the group M**1** to which the mobile station $MS_{M1\text{-}1}$ belongs from the home network HN. Next, in step **701**b, the home network HN authenticates the mobile station $MS_{M1\text{-}1}$ based on the identification data $AUTH_{M1}$. If the authentication succeeds, step **701**b is then executed; otherwise, the communication is terminated. In FIG. **7**, it is assumed that the home network HN successfully authenticates the mobile station $MS_{M1\text{-}1}$. After that, in step **701**c, the home network HN generates a group authentication data $AUTH_H$ based on the identification data $AUTH_{M1}$ and sends the group authentication data $AUTH_H$ and the requested group list to the serving network SN. In step **701**d, the group list and the group authentication data $AUTH_H$ are stored in the database of the serving network SN.

In FIG. **7**, it is assumed that the first MAC $MAC_{M1\text{-}1}$ and the second MAC $XMAC_{M1\text{-}1}$ are the same, i.e. the home network HN successfully authenticates the mobile station $MS_{M1\text{-}1}$. Since the serving network SN requests the group authentication data $AUTH_H$ from the home network HN on behalf of the mobile station $MS_{M1\text{-}1}$, it is ensured by foregoing authentication mechanism (the comparison between the first MAC $MAC_{M1\text{-}1}$ and the second MAC $XMAC_{M1\text{-}1}$) that the serving network SN does request the group authentication data $AUTH_H$ from the home network HN instead of requesting randomly.

The mobile station authentication and key distribution step **702** further includes steps **702**a~**702**h. First, in step **702**a, the serving network SN generates a serving network authentication data $AUTH_{SM1\text{-}1}$ based on the group authentication data $AUTH_H$, the group list, and the identification data $AUTH_{M1}$ and sends the serving network authentication data $AUTH_{SM1\text{-}1}$ to the mobile station $MS_{M1\text{-}1}$. In step **702**b, after receiving the serving network authentication data $AUTH_{SM1\text{-}1}$, the mobile station $MS_{M1\text{-}1}$ authenticates the serving network SN based on the serving network authentication data $AUTH_{SM1\text{-}1}$ in order to determine whether the serving network SN is a legitimate serving network authorized by the home network HN. If the serving network SN is legitimate to the mobile station $MS_{M1\text{-}1}$, step **702**d is executed; otherwise, the communication is terminated or re-authentication is requested. In FIG. **7**, the serving network SN is assumed to be authorized by the home network HN as a legitimate serving network to the mobile station $MS_{M1\text{-}1}$.

Thereafter, in step **702**c, the serving network SN calculates a master key MK in advance for subsequent secured communication while the mobile station $MS_{M1\text{-}1}$ authenticates the serving network SN. In step **702**d, the mobile station $MS_{M1\text{-}1}$ calculates the master key MK and a fifth MAC MAC_{M1} based on the serving network authentication data $AUTH_{SM1\text{-}1}$ and sends the fifth MAC MAC_{M1} to the serving network SN. In step **702**e, the serving network SN receives the fifth MAC MAC_{M1} and generates a sixth MAC $XMAC_{M1}$ based on the group list recorded in the database thereof and a group transient key (GTK) GTK_{M1}. The serving network SN compares the fifth MAC MAC_{M1} with the sixth MAC $XMAC_{M1}$ and generates an authentication result. In step **702**f, the serving network SN sends the authentication result to the mobile station $MS_{M1\text{-}1}$. In step **702**g, the mobile station $MS_{M1\text{-}1}$ receives and confirms the authentication result. If the authentication result shows that the authentication succeeds, the serving network SN and the mobile station $MS_{M1\text{-}1}$ enter step **702**h; otherwise, the communication is terminated. In FIG. **7**, it is assumed that the authentication is successful, thus, in step **702**h, the serving network SN and the mobile station $MS_{M1\text{-}1}$ generate a cipher key or an integrity key to secure subsequent communication by using the master key MK.

In aforementioned step **701**b, the home network HN authenticates the mobile station $MS_{M1\text{-}1}$. If the authentication operation fails, besides terminating the entire communication, the authentication procedure may be performed again starting from step **700**a or re-transmission of the identification data $AUTH_{M1}$ is requested. In aforementioned step **702**b, the mobile station $MS_{M1\text{-}1}$ authenticates the serving network SN in order to determine whether the serving network SN is a legitimate serving network authorized by the home network HN to the mobile station $MS_{M1\text{-}1}$. If the serving network SN is not legitimate to the mobile station $MS_{M1\text{-}1}$, the authentication procedure may be performed again (i.e. starting from step **700**a) or re-transmission of the group authentication data $AUTH_H$ or the serving network authentication data $AUTH_{SM1\text{-}1}$ may be requested besides terminating the communication.

In step **702**g, if the authentication result shows that the authentication fails, the authentication may be performed again (i.e. starting from step **700**a) or re-transmission of the fifth MAC MAC_{M1} may be requested besides terminating the communication.

FIG. **8** illustrates a method for generating the identification data $AUTH_{M1}$ in step **700**b illustrated in FIG. **7** according to an exemplary embodiment of the present invention. In the present invention, the mobile station $MS_{M1\text{-}1}$ generates a first random number $RN_{M1\text{-}1}$. The mobile station $MS_{M1\text{-}1}$ inputs the first random number $RN_{M1\text{-}1}$ and a mobile station authentication key $K_{M1\text{-}1}$ into the mobile station authentication message generation function f**0** to generate the first MAC

MAC$_{M1-1}$. The mobile station MS$_{M1-1}$ combines the group number G**1**, the mobile station ID MS**1**-**1**, the first random number RN$_{M1-1}$, and the first MAC MAC$_{M1-1}$ into the identification data AUTH$_{M1}$ (AUTH$_{M1}$={G**1**||MS**1**-**1**||RN$_{M1-1}$||MAC$_{M1-1}$}).

FIG. **9** illustrates how the home network HN authenticates the mobile station MS$_{M1-1}$ based on the identification data AUTH$_{M1}$ in step **701***b* illustrated in FIG. **7** according to an exemplary embodiment of the present invention. As shown in FIG. **9**, the home network HN obtains the first random number RN$_{M1-1}$ in the identification data AUTH$_{M1}$ and the first MAC MAC$_{M1-1}$. The home network then inputs the first random number RN$_{M1-1}$ and the mobile station authentication key K$_{M1-1}$ stored in the home network HN into the mobile station authentication message generation function f**0** to generate a second MAC XMAC$_{M1-1}$, the eXpected MAC of the mobile station MS$_{M1-1}$. The home network further compares the first MAC MAC$_{M1-1}$ with the second MAC XMAC$_{M1-1}$ generated by the home network HN. If the first MAC MAC$_{M1-1}$ is equal to the second MAC XMAC$_{M1-1}$, step **701***c* is then executed; otherwise, the communication is terminated.

FIG. **10** illustrates a method for generating the group authentication data AUTH$_{H}$ in step **701***c* illustrated in FIG. **7** according to an exemplary embodiment of the present invention. As shown in FIG. **10**, the home network HN first generates a second random number RN$_{H}$, and inputs the second random number RN$_{H}$, the group authentication key GAK**1**, a plurality of AMFs AMF, and the first random number RN$_{M1-1}$ in the identification data AUTH$_{M1}$ into the key generation function f**3** to calculate a GTK GTK$_{M1}$ which can be used to authenticate all mobile stations in the group M**1** in the serving network SN. After that, the home network HN combines the parameters required for generating the GTK GTK$_{M1}$ (the second random number RN$_{H}$, the AMFs AMF, and the first random number RN$_{M1-1}$) and the GTK GTK$_{M1}$ into the group authentication data AUTH$_{H}$ (AUTH$_{H}$={RN$_{H}$||AMF||RN$_{M1-1}$||GTK$_{M1}$}) and sends the group authentication data AUTH$_{H}$ to the serving network SN. Even though the first random number RN$_{M1-1}$ is generated by the mobile station MS$_{M1-1}$, since the other mobile stations in the group M**1** is unaware of the random number RN$_{M1-1}$ or may change the input of the key generation function f**3** to generate a new GTK, the other parameters (the second random number RN$_{H}$, the AMFs AMF, and the first random number RN$_{M1-1}$) excluding the group authentication key GAK**1** still have to be sent to the mobile station MS$_{M1-1}$ so that the mobile station MS$_{M1-1}$ can generate the GTK GTK$_{M1}$ accordingly.

FIG. **11** illustrates a method for generating the serving network authentication data AUTH$_{SM1-1}$ in step **702***a* illustrated in FIG. **7** according to an exemplary embodiment of the present invention. As shown in FIG. **11**, the serving network SN adds the authentication counter of the mobile station MS$_{M1-1}$ in the serving network SN to the initial value IV**1**-*l* of the mobile station MS$_{M1-1}$ in the group list to obtain a first transient total. After that, the serving network SN multiplies the first random number RN$_{M1-1}$ in the identification data AUTH$_{M1}$ by the first transient total to obtain a first transient product. Next, the serving network SN inputs the GTK GTK$_{M1}$ in the group authentication data AUTH$_{H}$ and the first transient product into the serving network authentication message generation function f^{1} to calculate a third MAC MAC$_{S}$.

Thereafter, the serving network SN generates a third random number RN$_{SM1-1}$. The serving network SN combines the AMFs AMF and the second random number RN$_{H}$ and the first random number RN$_{M1-1}$ retrieved from the group authentication data AUTH$_{H}$, the third MAC MAC$_{S}$, and the third random number RN$_{SM1-1}$ into a serving network authentication data AUTH$_{SM1-1}$ (AUTH$_{SM1-1}$={AMF||RN$_{H}$||RN$_{M1-1}$||MAC$_{S}$||RN$_{SM1-1}$}), where the AMFs AMF, the second random number RN$_{H}$, and the first random number RN$_{M1-1}$ are necessary parameters for the mobile station MS$_{M1-1}$ to generate the GTK GTK$_{M1}$, the third MAC MAC$_{S}$ is for the mobile station MS$_{M1-1}$ to authenticate the serving network SN, and the third random number RN$_{SM1-1}$ is for the mobile station MS$_{M1-1}$ to calculate the fifth MAC MAC$_{M1}$ which can be used by the serving network SN to authenticate the mobile station MS$_{M1-1}$.

FIG. **12** illustrates how the mobile station MS$_{M1-1}$ authenticates the serving network SN in step **702***b* illustrated in FIG. **7** according to an exemplary embodiment of the present invention. As shown in FIG. **12**, after the mobile station MS$_{M1-1}$ receives the serving network authentication data AUTH$_{SM1-1}$, the mobile station MS$_{M1-1}$ inputs the AMFs AMF, the second random number RN$_{H}$, and the first random number RN$_{M1-1}$ in the serving network authentication data AUTH$_{SM1-1}$ and the group authentication key GAK**1** stored in the mobile station MS$_{M1-1}$ into the key generation function f**3** to generate the GTK GTK$_{M1}$. After that, the mobile station MS$_{M1-1}$ calculates a fourth MAC XMAC$_{S}$. Next, the mobile station MS$_{M1-1}$ adds the initial value IV**1**-**1** of the mobile station MS$_{M1-1}$ to the authentication counter i of the mobile station MS$_{M1-1}$ in the serving network SN to obtain a second transient total. The mobile station MS$_{M1-1}$ then multiplies the second transient total by the first random number RN$_{M1-1}$ to obtain a second transient product. The mobile station MS$_{M1-1}$ inputs the second transient product and the GTK GTK$_{M1}$ into the serving network authentication message generation function f**1** to generate the fourth MAC XMAC$_{S}$. The mobile station MS$_{M1-1}$ compares the fourth MAC XMAC$_{S}$ with the third MAC MAC$_{S}$ in the serving network authentication data AUTH$_{SM1-1}$. If the fourth MAC XMAC$_{S}$ is equal to the third MAC MAC$_{S}$, the mobile station MS$_{M1-1}$ has successfully authenticated the serving network SN, and meanwhile, the mobile station MS$_{M1-1}$ has successfully authenticated the home network HN as well for the mobile station MS$_{M1-1}$ has to generate a correct GTK GTK$_{M1}$ in order to pass the subsequent authentication.

FIG. **13** illustrates a method for calculating the master key MK in step **702***c* illustrated in FIG. **7** according to an exemplary embodiment of the present invention. As shown in FIG. **13**, the serving network SN calculates the master key MK when the mobile station MS$_{M1-1}$ verifies the serving network authentication data AUTH$_{SM1-1}$ of the serving network SN, so that the time for calculating the master key MK can be saved when later on the mobile station MS$_{M1-1}$ sends the MAC$_{M1}$ for authenticating the mobile station MS$_{M1-1}$ back to the serving network SN and the serving network SN successfully authenticates the mobile station MS$_{M1-1}$. The serving network SN inputs the first random number RN$_{M1-1}$, the third random number RN$_{SM1-1}$, the first transient total (IV**1**-**1**+i), and the GTK GTK$_{M1}$ into the key generation function f**3** to calculate the master key MK.

Foregoing step **702***c* may also be executed after the mobile station MS$_{M1-1}$ sends the fifth MAC MAC$_{M1}$ to the serving network SN and the serving network SN successfully authenticates the mobile station MS$_{M1-1}$. However, in the present embodiment, the time required by the serving network SN for calculating the master key MK can be saved.

FIG. **14** illustrates a method for calculating the master key MK and generating the fifth MAC MAC$_{M1}$ in step **702***d* illustrated in FIG. **7** according to an exemplary embodiment of the present invention. As shown in FIG. **14**, after the mobile station $MS_{M1\text{-}1}$ successfully authenticates the serving network SN as a legitimate serving network, the mobile station $MS_{M1\text{-}1}$ generates the fifth MAC MAC_{M1} which allows the serving network SN to authenticate the mobile station $MS_{M1\text{-}1}$. The mobile station $MS_{M1\text{-}1}$ first adds the initial value IV**1-1** which is only known to the serving network SN and the mobile station $MS_{M1\text{-}1}$ to the authentication counter i of the mobile station $MS_{M1\text{-}1}$ in the serving network SN to obtain a third transient total, and then the mobile station $MS_{M1\text{-}1}$ multiplies the third transient total by the third random number $RN_{SM1\text{-}1}$ in the serving network authentication data $AUTH_{SM1\text{-}1}$ to obtain a third transient product.

After that, the mobile station $MS_{M1\text{-}1}$ inputs the GTK GTK_{M1} and the third transient product into the group authentication message generation function f**2** to calculate the fifth MAC MAC_{M1} for the serving network SN to authenticate the mobile station $MS_{M1\text{-}1}$. Besides, the mobile station $MS_{M1\text{-}1}$ also inputs the first random number $RN_{M1\text{-}1}$, the third random number $RN_{SM1\text{-}1}$, the third transient total, and the GTK GTK_{M1} into the key generation function f**3** to calculate the master key MK for subsequent secured communication between the mobile station $MS_{M1\text{-}1}$ and the serving network SN.

FIG. **15** illustrates a method for generating the authentication result in step **702***e* illustrated in FIG. **7** according to an exemplary embodiment of the present invention. As shown in FIG. **15**, the serving network SN first adds the number i, the authentication times performed by the mobile station $MS_{M1\text{-}1}$ to the serving network SN, to the initial value IV**1-1** to obtain a fourth transient total, and then the serving network SN multiplies the fourth transient total by the third random number $RN_{SM1\text{-}1}$ to obtain a fourth transient product. After that, the serving network SN inputs the fourth transient product and the GTK GTK_{M1} into the group authentication message generation function f**2** to calculate a sixth MAC $XMAC_{M1}$. Finally, the serving network SN compares the sixth MAC $XMAC_{M1}$ with the fifth MAC MAC_{M1} to obtain an authentication result.

Foregoing authentication methods performed by the mobile station $MS_{M1\text{-}1}$ to the serving network SN and the home network HN, by the serving network SN to the mobile station $MS_{M1\text{-}1}$, and by the home network HN to the mobile station $MS_{M1\text{-}1}$ are only an exemplary embodiment of the present invention but not for restricting the present invention. It should be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention.

FIG. **16** is a flowchart of a group authentication method according to an another exemplary embodiment of the present invention, wherein the mobile station $MS_{M1\text{-}2}$ is not the first mobile station which hands off among all the mobile stations in the same group M**1**. Since the mobile station $MS_{M1\text{-}2}$ is not the first handoff mobile station in the group M**1**, the serving network SN can directly obtain the GTK GTK_{M1} from the database thereof and transmits the necessary parameters for generating GTK_{M1} to the mobile station $MS_{M1\text{-}2}$. Thus, after the mobile station $MS_{M1\text{-}2}$ has obtained the parameters for generating the GTK GTK_{M1} and has calculated the GTK GTK_{M1}, the mobile station $MS_{M1\text{-}2}$ and the serving network SN can directly authenticate each other without requesting assistant from the home network HN. The traffic load between the home network HN and the serving network SN can be reduced.

Additionally, the mobile station $MS_{M1\text{-}2}$ may also request the serving network SN to perform a full authentication as illustrated in FIG. **7**, namely, the serving network SN can determine whether a full authentication is to be performed based on the message received from the mobile station $MS_{M1\text{-}2}$, and the serving network SN can send an authentication message back to the home network HN and request a fresh group authentication data $AUTH_H$. The group authentication method illustrated in FIG. **16** includes an identification step **1600**, a GTK retrieving step **1601**, and a mobile station authentication and key distribution step **1602**, wherein the identification step **1600** and the GTK retrieving step **1601** belong to aforementioned registration and authentication data distribution procedure, and the mobile station authentication and key distribution step **1602** belongs to aforementioned user authentication and key agreement procedure. In the present invention, local authentication refers to the execution of the GTK retrieving step **1601** and the mobile station authentication and key distribution step **1602**. As the name of local authentication implies, the serving network SN only authenticates the mobile station $MS_{M1\text{-}2}$ and does not request the home network HN to authenticate the mobile station $MS_{M1\text{-}2}$.

First, the identification step **1600** further includes steps **1600***a*-**1600***c*. In step **1600***a*, the serving network SN requests an identification data from the mobile station $MS_{M1\text{-}2}$. Next, in step **1600***b*, the mobile station $MS_{M1\text{-}2}$ generates the identification data $AUTH_{M1}$ and sends the identification data $AUTH_{M1}$ to the serving network SN, wherein the identification data $AUTH_{M1}$ contains a mobile station ID MS**1-2** of the mobile station $MS_{M1\text{-}2}$ so that the serving network SN can identify the mobile station $MS_{M1\text{-}2}$ based on the mobile station ID MS**1-2**. Then in step **1600***c*, the serving network SN receives the identification data $AUTH_{M1}$ generated by the mobile station $MS_{M1\text{-}2}$ and identifies the mobile station $MS_{M1\text{-}2}$. The serving network SN determines whether the mobile station ID MS**1-2** is recorded in the group list in the database of the serving network SN.

Since the mobile station $MS_{M1\text{-}2}$ is not the first mobile station which enters the serving network SN among all the mobile stations in the group M**1**, mobile station ID MS**1-2** is already recorded in the group list in the database of the serving network SN, thus, the entire procedure proceeds to the GTK retrieving step **1601**. Besides, the mobile station $MS_{M1\text{-}2}$ may also request the serving network SN to perform a full authentication action as illustrated in FIG. **7**. For example, a flag is further attached into the identification data $AUTH_{M1}$ to indicate whether the serving network SN has to perform a full authentication or not even though the mobile station ID MS**1-2** has been recorded in the group list in the database of the serving network SN. In FIG. **16**, it is assumed that the mobile station $MS_{M1\text{-}2}$ does not request the serving network SN to perform a full authentication action as illustrated in FIG. **7**.

The GTK retrieving step **1601** includes the following step. The serving network SN retrieves the group authentication data $AUTH_H$ of the group M**1** of the mobile station $MS_{M1\text{-}2}$ from the database of the serving network SN, where the group authentication data $AUTH_H$ contains the GTK GTK_{M1} ($AUTH_H=\{RN_H\|AMF\|RN_{M1\text{-}1}\|GTK_{M1}\}$). After that, the mobile station authentication and key distribution step **1602** is executed.

The mobile station authentication and key distribution step **1602** further includes steps **1602***a*~**1602***h*. In step **1602***a*, the serving network SN generates a serving network authentication data $AUTH_{SM1\text{-}2}$ based on the group authentication data $AUTH_H$ and sends the serving network authentication data $AUTH_{SM1\text{-}2}$ to the mobile station $MS_{M1\text{-}2}$. After that, in step **1602***b*, the mobile station $MS_{M1\text{-}2}$ receives the serving network authentication data $AUTH_{SM1\text{-}2}$ and authenticates the serving network SN based on the serving network authentication data AUTH$_{SM1-2}$ in order to determine whether the serving network SN is a legitimate serving network authorized by the home network HN. If the serving network SN is legitimate to the mobile station MS$_{M1-2}$, step **1602***d* is executed; otherwise, the communication is terminated. In FIG. **16**, it is assumed that the serving network SN is legitimate to the mobile station MS$_{M1-2}$.

Thereafter, in step **1602***c*, the serving network SN calculates a master key MK for subsequent secured communication while the mobile station MS$_{M1-2}$ authenticates the serving network SN. Next, in step **1602***d*, the mobile station MS$_{M1-2}$ calculates the master key MK and a fifth MAC MAC$_{M1}$ based on the serving network authentication data AUTH$_{SM1-2}$ and sends the fifth MAC MAC$_{M1}$ to the serving network SN. In step **1602***e*, the serving network SN receives the fifth MAC MAC$_{M1}$ and then generates a sixth MAC XMAC$_{M1}$, the eXpected MAC of the aforementioned fifth MAC MAC$_{M1}$, based on the GTK GTK$_{M1}$ and the information recorded in the group list in the database thereof, and the serving network SN then compares the fifth MAC MAC$_{M1}$ and the sixth MAC XMAC$_{M1}$ and generates an authentication result.

In step **1602***f*, the serving network SN sends the authentication result to the mobile station MS$_{M1-2}$. In step **1602***g*, the mobile station MS$_{M1-2}$ confirms the authentication result. If the authentication result shows that the authentication succeeds, the serving network SN and the mobile station MS$_{M1-2}$ enter step **1602***h*; otherwise, if the authentication result shows that the authentication fails, the communication is terminated. In FIG. **16**, it is assumed that the authentication is successful. In step **1602***h*, the serving network SN and the mobile station MS$_{M1-2}$ use the master key MK to secure the subsequent communication.

In foregoing step **1602***b*, the mobile station MS$_{M1-2}$ authenticates the serving network SN and determines whether the serving network SN is a legitimate serving network authorized by the home network HN. If the serving network SN is not legitimate to the mobile station MS$_{M1-2}$, the authentication action may be performed again (starting from step **1600***a*) or the serving network authentication data AUTH$_{SM1-1}$ may be re-transmitted besides terminating the communication. In step **1602***g*, if the authentication result shows that the authentication fails, the authentication action may be performed again (starting from step **1600***a*) or the fifth MAC MAC$_{M1}$ may be re-transmitted besides terminating the communication.

FIG. **17** illustrates a method for generating the identification data AUTH$_{M1}$ in step **1600***b* illustrated in FIG. **16** according to an exemplary embodiment of the present invention. In the present embodiment, the mobile station MS$_{M1-2}$ generates a first random number RN$_{M1-2}$. The mobile station MS$_{M1-2}$ inputs the first random number RN$_{M1-2}$ and a mobile station authentication key K$_{M1-2}$ into the mobile station authentication message generation function f**0** to generate a first MAC MAC$_{M1-2}$. The mobile station MS$_{M1-2}$ combines a group number G**1**, the mobile station ID MS**1-2**, the first random number RN$_{M1-2}$, and the first MAC MAC$_{M1-2}$ into an identification data AUTH$_{M1}$ (AUTH$_{M1}$={G**1**||MS**1-2**||RN$_{M1-2}$||MAC$_{M1-2}$}).

FIG. **18** illustrates a method for generating the serving network authentication data AUTH$_{SM1-2}$ in step **1602***a* illustrated in FIG. **16** according to an exemplary embodiment of the present invention. In the present embodiment, the serving network SN first adds the authentication counter i of the mobile station MS$_{M1-2}$ in the serving network SN to the initial value IV**1-2** of the mobile station MS$_{M1-2}$ in the group list to obtain a first transient total. After that, the serving network SN multiplies the first random number RN$_{M1-2}$ in the mobile station identification data AUTH$_{M1}$ by the first transient total to obtain a first transient product. Next, the serving network SN retrieves the GTK GTK$_{M1}$ from the database thereof and inputs the GTK GTK$_{M1}$ and the first transient product into the serving network authentication message generation function f**1** to calculate a third MAC MAC$_S$. Then, the serving network SN generates a third random number RN$_{SM1-2}$, and the serving network SN combines the AMFs AMF and the second random number RN$_H$ retrieved from the database thereof, the first random number RN$_{M1-1}$ in the identification data AUTH$_{M1}$, the third MAC MAC$_S$, and the third random number RN$_{SM1-2}$ into the serving network authentication data AUTH$_{SM1-2}$ (AUTH$_{SM1-2}$={AMF||RN$_H$||RN$_{M1-1}$||MAC$_S$||RN$_{SM1-2}$}). The AMFs AMF, the second random number RN$_H$, and the first random number RN$_{M1-1}$ are used by the mobile station MS$_{M1-2}$ to generate the GTK GTK$_{M1}$, the third MAC MAC$_S$ is for the mobile station MS$_{M1-2}$ to authenticate the serving network SN, and the third random number RN$_{SM1-2}$ is used by the mobile station MS$_{M1-2}$ to calculate the MAC$_{M1}$ which can be used by the serving network SN for authenticating the mobile station MS$_{M1-2}$.

FIG. **19** illustrates how the mobile station MS$_{M1-2}$ authenticates the serving network SN in step **1602***b* illustrated in FIG. **16** according to an exemplary embodiment of the present invention. In the present embodiment, after the mobile station MS$_{M1-2}$ receives the serving network authentication data AUTH$_{SM1-2}$, the mobile station MS$_{M1-2}$ inputs the AMFs AMF, the second random number RN$_H$, and the first random number RN$_{M1-1}$ in the serving network authentication data AUTH$_{SM1-2}$ and the group authentication key GAK**1** stored in the mobile station MS$_{M1-2}$ into the key generation function f**3** to generate the GTK GTK$_{M1}$. After that, the mobile station MS$_{M1-2}$ continues to calculate the fourth MAC XMAC$_S$, the eXpected MAC to authenticate the serving network SN.

Next, the mobile station MS$_{M1-2}$ adds the initial value IV**1-2** of the mobile station MS$_{M1-2}$ to the authentication counter i of the mobile station MS$_{M1-2}$ in the serving network to get a second transient total, and then multiplies the second transient total by and the first random number RN$_{M1-2}$ to obtain a second transient product. The mobile station MS$_{M1-2}$ inputs the second transient product and the GTK GTK$_{M1}$ into the serving network authentication message generation function f**1** to generate the fourth MAC XMAC$_S$. The mobile station MS$_{M1-2}$ compares the fourth MAC XMAC$_S$ with the third MAC MAC$_S$ in the serving network authentication data AUTH$_{SM1-2}$. If the fourth MAC XMAC$_S$ is equal to the third MAC MAC$_S$, the mobile station MS$_{M1-2}$ has successfully authenticated the serving network SN, and meanwhile, the mobile station MS$_{M1-2}$ has successfully authenticated the home network HN as well for that the mobile station MS$_{M1-2}$ has to generate a correct GTK GTK$_{M1}$ in order to pass the subsequent authentication.

FIG. **20** illustrates a method for calculating the master key MK in step **1602***c* illustrated in FIG. **16** according to an exemplary embodiment of the present invention. In the present embodiment, the serving network SN calculates the master key MK while the mobile station MS$_{M1-2}$ verifies the serving network authentication data AUTH$_{SM1-2}$ of the serving network SN, so that the time for calculating the master key MK can be saved when later on the mobile station MS$_{M1-2}$ sends the MAC$_{M1}$ for the serving network SN to authenticate the mobile station MS$_{M1-2}$ to the serving network SN and the serving network SN successfully authenticates the mobile station MS$_{M1-2}$. The serving network SN inputs the first random number RN$_{M1-2}$, the third random number RN$_{SM1-1}$, the second transient total (IV**1**-**2**+i), and the GTK GTK_{M1} into the key generation function f^3 to calculate the master key MK.

The aforementioned step **1602***c* may also be executed after the mobile station MS_{M1-2} sends the fifth MAC MAC_{M1} to the serving network SN and the serving network SN successfully authenticates the mobile station MS_{M1-2}. However, in the present embodiment, the time required by the serving network SN for calculating the master key MK can be saved.

FIG. **21** illustrates a method for calculating the master key MK and generating a fifth MAC MAC_{M1} in step **1602***d* illustrated in FIG. **16** according to an exemplary embodiment of the present invention. In the present embodiment, after the mobile station MS_{M1-2} successfully authenticates the serving network SN as a legitimate serving network, the mobile station MS_{M1-2} generates the fifth MAC MAC_{M1} which allows the serving network SN to authenticate the mobile station MS_{M1-2}. The mobile station MS_{M1-2} first adds the initial value IV**1**-**2** which is only known to the serving network SN and the mobile station MS_{M1-2} to the authentication counter i of the mobile station MS_{M1-2} in the serving network SN to get a third transient total, and then the mobile station MS_{M1-2} multiplies the third transient total by the third random number RN_{SM1-2} in the serving network authentication data $AUTH_{SM1-2}$ to get a third transient product.

After that, the mobile station MS_{M1-2} inputs the GTK GTK_{M1} and the third transient product into the group authentication message generation function f**2** to calculate the fifth MAC MAC_{M1} which allows the serving network SN to authenticate the mobile station MS_{M1-2}. Besides, the mobile station MS_{M1-2} also inputs the first random number RN_{M1-2}, the third random number RN_{SM1-2}, the third transient total, and the GTK GTK_{M1} generated by the mobile station MS_{M1-2} into the key generation function f**3** to calculate the master key MK to secure subsequent communication between the mobile station MS_{M1-2} and the serving network SN.

FIG. **22** illustrates a method for generating the authentication result in step **1602***e* illustrated in FIG. **16** according to an exemplary embodiment of the present invention. In the present embodiment, the serving network SN first adds the counter i, which records the times of authentications performed by the mobile station MS_{M1-2} to the serving network SN to the initial value IV**1**-**2** to get a fourth transient total, and then the serving network SN multiplies the fourth transient total by the third random number RN_{SM1-2} to obtain a fourth transient product. After that, the serving network SN inputs the fourth transient product and the GTK GTK_{M1} into the group authentication message generation function f**2** to calculate a sixth MAC $XMAC_{M1}$. Finally, the serving network SN compares the sixth MAC $XMAC_{M1}$ with the fifth MAC MAC_{M1} to get an authentication result.

The aforementioned authentication methods performed by the mobile station MS_{M1-2} to the serving network SN and the home network HN and by the serving network SN to the mobile station MS_{M1-2} are only an exemplary embodiment of the present invention but not for restricting the present invention. It should be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention.

The mobile stations MS_{M1-1} and MS_{M1-2} illustrated in FIG. **7** and FIG. **16** belong to the group M**1**. However, foregoing example is only used for describing the present invention, and actually the mobile stations MS_{M1-1} and MS_{M1-2} may also belong to other groups (i.e. the mobile stations MS_{M1-1} and MS_{M1-2} may belong to at least one group).

The group authentication method proposed by the present invention may be applied to a cellular network. When a first mobile station in a user group visits a serving network and passes the authentication, an authentication server of the visited serving network stores a group authentication data of the user group. Later on, when a mobile station in the user group visits this serving network, the mobile station is not authenticated directly with the authentication server of the registered home network (home AAA server, H-AAA); instead, the mobile station is authenticated through the authentication server of the visited serving network (visited AAA server, V-AAA). Accordingly, in the present invention, the signalling overhead caused by the transmission of the group authentication data between the H-AAA and the V-AAA is reduced without losing the security thereof.

The group authentication method proposed by the present invention may also be applied to an 802.11 network. FIG. **23** illustrates an application of the group authentication method provided by the present invention in an 802.11 network. Referring to FIG. **23**, the MN group includes a plurality of mobile stations MN_1~MN_n which hand off at the same access point (AP) AP_1 of the 802.11 network and the AP AP_1 authenticates the mobile stations MN_1~MN_n. When the AP AP_1 authenticates the mobile station MN_1, the AP AP_1 requests a group authentication data and a group list from the AAA server of the home network. The AAA server sends the group authentication data and the group list used for authenticating the mobile stations MN_1~MN_n to the AP AP_1. After the AP AP_1 has authenticated the mobile station MN_1, the AP AP_1 can authenticate the mobile station MN_2 by directly using the group authentication data previously obtained for authenticating the mobile station MN_1.

The group authentication method proposed by the present invention may also be applied to a handheld game device. Handheld game devices usually exchange messages by low power radio waves, thus, the operation of these handheld game devices may be affected by the environment and the distances between the devices. Moreover, when a user wants to play an online game through a wireless network, the quality of real-time communication may be damaged due to handoff of the device. Through the group authentication method in the present invention, two handheld game devices which perform end-to-end video/audio transmission are considered as two mobile stations in the same group. When the two handheld game devices roam together, one of the two devices can perform only a local authentication to the visited serving network after the other device has performed a full authentication. Therefore, the transmission of real-time data between the two handheld game devices will not be affected by the handoff authentication procedure.

The group authentication method proposed by the present invention may also be applied to an access control system. For the security of a company, the employee authentication data in the access control system of the company has to be discarded after an authentication is performed. Through the group authentication method in the present invention, the employees in the same department or of the entire company are considered mobile stations in the same group. A simulated member can be regarded as the first member who requests for authentication so that all the authentication data can be predistributed from a user database to an authentication machine of the access control system before real users access the security system. In this way, when an employee is authenticated, the time required for transmitting authentication messages between the access control system and the user database can be saved.

FIG. **24** illustrates an application of the group authentication method proposed by the present invention for mobile routers (MRs). MRs are disposed in buses BUS**1**~BUS**4** so that passengers on the buses BUS1~BUS4 can access the Internet through these MRs. The MRs disposed in the buses BUS1~BUS4 of the same route are considered mobile stations in the same group. These MRs tend to roam to the same serving network SN, follow the same route along with the buses BUS1~BUS4, and belong to the same home network HN. The MRs in the same group have a group authentication key. When these MRs roam along the same route, network delay caused by frequent authentication on the route can be reduced and the handoff efficiency of the MRs can be increased by using the shared group authentication data, and accordingly, high quality real-time services (for example, VoIP) can be provided in the buses.

The group authentication method proposed by the present invention may also be applied to the group communication in a terrestrial trunked radio (TETRA) network. Mobile stations in the TETRA network have a group characteristic (group communication or group movement). In other words, some mobile stations in the TETRA network may communicate with each other or move together at the same time for particular purposes. Accordingly, a group security mechanism is provided to protect the data transmitted when a mobile station group is performing group communication. Since the TETRA network itself already has a group characteristic, the group authentication method proposed by the present invention can be applied directly to the TETRA network without changing the structure of the TETRA network, so that the handoff efficiency of a mobile station group can be increased.

In summary, according to the group authentication method proposed by the present invention, when a mobile station hands off for the first time among all the mobile stations in a user group, the mobile station performs a full authentication to the serving network. During the full authentication procedure, the serving network obtains a GTK from the home network of the mobile station, so that the subsequent mobile stations in the same group can be authenticated by the serving network through local authentication by using the GTK stored in the database of the serving network, and accordingly the authentication and re-authentication of all the mobile stations in the group can be simplified as long as the GTK is valid.

Compared to the conventional techniques, the group authentication method proposed by the present invention is more suitable for a system which provides real-time video/audio communication or group communication. Two mobile stations on end-to-end video/audio communication can be considered as two mobile stations in the same group. When the two mobile stations roam together, one of the two mobile stations perform only a local authentication after the other mobile station has performed a full authentication to the serving network, so that the transmission of real-time data will not be affected by the handoff authentication procedure.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.

What is claimed is:

1. A group authentication method adaptable to a communication system, wherein the communication system comprises a first group, a serving network, and a home network, the first group comprises at least one mobile station, the serving network has a first database for recording a plurality of group lists and group authentication data received from the home network, the home network pre-distributes a group authentication key and a mobile station authentication key to the mobile station and itself, the home network has a second database for recording the group lists generated by the home network, and the group authentication method comprises:

identifying action to the mobile station through the serving network; and determining whether the communication system performs a full authentication action or a local authentication action through the serving network according to the result of the identification action, and

a mobile station authentication and key distribution step;

wherein the full authentication action comprises: the execution of the home network authentication, the mobile station authentication, and key distribution;

wherein the local authentication action comprises:

a transient authentication key obtaining step, wherein the transient authentication key obtaining step comprises: retrieving the group authentication data from the first database through the serving network, wherein the group authentication data contains which contains a group transient key (GTK) generated at the home network according to the group authentication key;

wherein the group list comprises a group number, the group authentication key, a mobile station ID, an initial value, and a group related message, and the mobile station has the group number, the mobile station ID, and the initial value;

wherein the identification action comprises: requesting an identification data from the mobile station through the serving network;

generating a first random number through the mobile station, and then generating the identification data according to the mobile station authentication key and the first random number through the mobile station; and

transmitting the identification data to the serving network from the mobile station;

wherein the mobile station has a mobile station authentication message generation function, and the method for generating the identification data comprises:

inputting the first random number and the mobile station authentication key into the mobile station authentication message generation function stored in the mobile station to calculate a first message authentication code (MAC); and

combining the group number, the mobile station ID, the first random number, and the first MAC through the mobile station to generate the identification data.

2. The group authentication method according to claim **1**, wherein the serving network determines whether the communication system performs the full authentication action or the local authentication action based on whether the mobile station requires the communication system to perform the full authentication action or not, the communication system performs the full authentication action if the mobile station requires the communication system to perform the full authentication action,

the serving network determines whether the mobile station ID in the identification data received from the mobile station is in the group list recorded in the first database inside the serving network if the mobile station does not require the communication system to perform the full authentication action,

the communication system performs the full authentication action if the mobile station ID in the identification data received from the mobile station is not in the group list recorded in the first database, and

the communication system performs the local authentication action if the mobile station ID in the identification data received from the mobile station is in the group list recorded in the first database.

3. The group authentication method according to claim 2, wherein the full authentication action comprises: a home network authentication step; and a mobile station authentication and key distribution step.

4. The group authentication method according to claim 3, wherein the home network authentication step comprises:

transmitting the identification data to the home network through the serving network, and requesting the group list of the mobile station and the group authentication data from the home network through the serving network;

authenticating the mobile station according to the identification data through the home network; and

generating the group authentication data and transmitting the group authentication data and the group list of the mobile station to the serving network through the home network if the home network successfully authenticates the mobile station; and storing the group authentication data and the group list of the mobile station into the first database inside the serving network.

5. The group authentication method according to claim 4, wherein the home network further has the mobile station authentication message generation function, and the method is for the home network to authenticate the mobile station according to the identification data comprises:

capturing the first random number and the first MAC of the identification data through the home network, and inputting the first random number and the mobile station authentication key into the mobile station authentication message generation function through the home network to generate a second MAC; and

comparing the first MAC and the second MAC through the home network, wherein the home network successfully authenticates the mobile station if the first MAC and the second MAC are the same.

6. The group authentication method according to claim 5, wherein the home network has a key generation function and a plurality of authentication management fields (AMFs), and the method for generating the group authentication data comprises:

generating a second random number through the home network, and inputting the first random number, the second random number, the group authentication key, and the AMFs into the key generation function through the home network to calculate a group transient key (GTK); and

combining the second random number, the AMFs, the first random number, and the GTK through the home network to generate the group authentication data.

7. The group authentication method according to claim 6, wherein the mobile station authentication and key distribution step comprises:

generating a serving network authentication data according to the group authentication data, the group list, and the identification data through the serving network,

and transmitting the serving network authentication data to the mobile station through the serving network;

receiving the serving network authentication data through the mobile station, and then authenticating the serving network according to the serving network authentication data through the mobile station, so as to determine whether the serving network is legitimate to the mobile station;

calculating a master key through the serving network if the serving network is legitimate to the mobile station;

calculating the master key and a fifth MAC according to the serving network authentication data through the mobile station, and then transmitting the fifth MAC to the serving network through the mobile station;

receiving the fifth MAC through the serving network, and generating a sixth MAC according to the group list recorded in the first database and the GTK through the serving network, and comparing the fifth MAC and the sixth MAC through the serving network to generate an authentication result;

transmitting the authentication result to the mobile station through the serving network; and

confirming the authentication result through the mobile station, wherein if the authentication result shows that the authentication is successful, then the serving network and the mobile station performs a secured communication by using the master key.

8. The group authentication method according to claim 7, wherein the serving network has a serving network authentication message generation function, and the method for generating the serving network authentication data comprises:

adding an authentication number of the mobile station which represents the times of authentication performed in the serving network to the initial value through the serving network to obtain a first transient total;

multiplying the first random number by the first transient total through the mobile station to obtain a first transient product;

inputting the GTK and the first transient product into the serving network authentication message generation function through the mobile station to calculate a third MAC; and

generating a third random number through the serving network, and combining the AMFs, the second random number, the first random number, the third MAC, and the third random number into the serving network authentication data through the serving network.

9. The group authentication method according to claim 8, wherein the mobile station has the serving network authentication message generation function and the key generation function, and the method for the mobile station to authenticate the serving network according to the serving network authentication data comprises:

receiving the serving network authentication data and obtaining the AMFs, the second random number, and the first random number in the serving network authentication data through the mobile station, and inputting the AMFs, the second random number, the first random number, and the group authentication key into the key generation function through the mobile station to generate the GTK;

adding the initial value to the authentication number of the mobile station in the current serving network through the mobile station to obtain a second transient total;

multiplying the second transient total by the first random number through the mobile station to obtain a second transient product;

inputting the second transient product and the GTK into the serving network authentication message generation function through the mobile station to generate a fourth MAC; and then

comparing the fourth MAC and the third MAC in the serving network authentication data through the mobile station.

10. The group authentication method according to claim **9**, wherein the serving network has the key generation function, and the method for the serving network to calculate the master key comprises:

inputting the first random number, the third random number, and the GTK into the key generation function through the serving network to calculate the master key.

11. The group authentication method according to claim **10**, wherein the mobile station has a group authentication message generation function, and

the method for the mobile station to generate the fifth MAC comprises:

adding the initial value and the authentication number through the mobile station to obtain a third transient total and multiplying the third transient total by the third random number through the mobile station to obtain a third transient product if the mobile station successfully authenticates the serving network as a legitimate serving network; and

then inputting the GTK and the third transient product into the group authentication message generation function through the mobile station to calculate the fifth MAC.

12. The group authentication method according to claim **11**, wherein the method for the mobile station to generate the master key comprises:

inputting the first random number, the third random number, and the GTK into the key generation function through the mobile station to generate the master key.

13. The group authentication method according to claim **12**, wherein the serving network has the group authentication message generation function, and the method for generating the sixth MAC comprises:

adding the authentication number to the initial value through the serving network to obtain a fourth transient total, and multiplying the fourth transient total by the third random number through the serving network to obtain a fourth transient product; and

inputting the fourth transient product and the GTK into the group authentication message generation function through the serving network to calculate the sixth MAC.

14. The group authentication method according to claim **1**, wherein the communication system further comprises a second group, and the mobile station can belong to both the first group and the second group.

15. A group authentication method adaptable to authentications between a home network, a serving network, and a user group, wherein the user group has at least one mobile station, the mobile station and the home network have a group authentication key and a mobile station authentication key, the home network has a group list, the mobile station has a mobile station ID, a group number, and an initial value, the serving network has a database for recording the group list received from the home network, and the group authentication method comprises:

generating an identification data in the mobile station, wherein the identification data comprises a first MAC and the mobile station ID; transmitting the identification data to the serving network through the mobile station;

determining whether the mobile station ID is in the group list recorded in the database through the serving network, if the mobile station ID is not in the group list recorded in the database:

transmitting the identification data to the home network through the serving network;

generating a second MAC in the home network according to the identification data;

comparing the first MAC and the second MAC, wherein the home network authenticates the mobile station successfully if the first MAC and the second MAC are the same;

generating a GTK in the home network by using the group authentication key;

transmitting a group authentication data and the group list to the serving network, wherein the group authentication data comprises the GTK; and

recording the group list and the group authentication data in the database of the serving network;

if the mobile station ID is found in the group list recorded in the database:

obtaining the group authentication data from the database of the serving network according to the mobile station ID; generating a third MAC in the serving network by using the group authentication data;

transmitting a serving network authentication data to the mobile station, wherein the serving network authentication data comprises the third MAC;

generating the GTK in the mobile station by using the group authentication key recorded in the mobile station and the serving network authentication data received from the serving network;

the mobile station generating a fourth MAC in the mobile station by using the comparing the third MAC and the fourth MAC in the mobile station, wherein the mobile station authenticates the serving network and the home network successfully if the third MAC and the fourth MAC are the same;

calculating a master key in the serving network by using the group authentication data and the identification data received from the mobile station;

generating the master key and a fifth MAC in the mobile station by using the serving network authentication data and the GTK;

transmitting the fifth MAC to the serving network through the mobile station;

generating a sixth MAC in tile serving network by using the group authentication data;

comparing the fifth MAC and the sixth MAC in the serving network, wherein the serving network authenticates the mobile station successfully if the fifth MAC and the sixth MAC are the same; and

both the serving network and the mobile station transmitting encrypted data by using the master key, so as to perform a secured communication between the serving network and the mobile station.

16. The group authentication method according to claim **15**, wherein the group list comprises the group number, the group authentication key, the mobile station ID, the initial value, and a group related message.

17. The group authentication method according to claim **15**, wherein the identification data further comprises a flag, and the flag is used for indicating that whether the mobile station requests the serving network to obtain new group authentication data from the home network or not.

18. The group authentication method according to claim **15**, wherein the method for generating the first MAC comprises:

generating a first random number in the mobile station; and calculating the first MAC by using the first random number and the mobile station authentication key.

19. The group authentication method according to claim **15**, wherein the identification data further comprises the first random number and the group number.

20. The group authentication method according to claim **15**, wherein the method for generating the second MAC in the home network according to the identification data comprises:

calculating the second MAC by using the first random number in the identification data and the mobile station authentication key recorded in the home network.

21. The group authentication method according to claim **15**, wherein the home network has a plurality of AMFs, and the method for generating the GTK in the home network by using the group authentication key comprises:

generating a second random number in the home network; and

calculating the GTK by using the AMFs, the second random number, the first random number, and the group authentication key.

22. The group authentication method according to claim **21**, wherein the group authentication data further comprises the AMFs, the first random number, and the second random number.

23. The group authentication method according to claim **22**, wherein the method for generating the third MAC in the serving network by using the group authentication data comprises:

calculating the third MAC by using the initial value in the group list, the number of the mobile station authenticating the serving network, the first random number, and the GTK.

24. The group authentication method according to claim **22**, wherein the serving network generates a third random number, and the serving network authentication data further comprises the first random number, the second random number, the AMFs, and the third random number.

25. The group authentication method according to claim **24**, wherein the method for generating the GTK in the mobile station by using the serving network authentication data and generating the fourth MAC in the mobile station by using the GTK comprises:

calculating the GTK by using the AMFs, the first random number, the second random number, and the group authentication key record in the mobile station; and

calculating the fourth MAC by using the GTK, the initial value, and the number of the mobile station authenticating the serving network.

26. The group authentication method according to claim **24**, wherein the method for calculating the master key in the serving network by using the group authentication data comprises:

calculating the master key by using the GTK, the first random number, and the third random number.

27. The group authentication method according to claim **25**, wherein the method for generating the master key and the fifth MAC in the mobile station by using the serving network authentication data and the GTK comprises:

generating the fifth MAC by using the third random number, the initial value, the number of the mobile station authenticating the serving network, and the GTK; and

calculating the master key by using the GTK, the first random number, and the third random number.

28. The group authentication method according to claim **24**, wherein the method for generating the sixth MAC in the serving network by using the group authentication data comprises:

generating the sixth MAC by using the third random number, the initial value, the number of the mobile station authenticating the serving network, and the GTK.

29. The group authentication method according to claim **15**, wherein the communication system further comprises a second group, and the mobile station can belong to both the first group and the second group.

* * * * *