WIRELESS MOBILE COMMUNICATION - A STUDY OF 4G TECHNOLOGY

S. B. Akintoye
Department of Computer Science, Babcock University, Ilishan-Remo, Ogun State; Nigeria.

ABSTRACT
Mobile communication is one of the hottest areas and it is developing extremely fast in present times with advanced techniques emerging in all the fields of mobile and wireless communications. The exponential growth of user demands, the limitations of the Third Generation of Mobile Communication Systems(3G) and the emergence of new mobile broadband technologies on the market have brought researchers to a throughout reflection on the Fourth Generation (4G).The purpose of this paper is to provide an overview of the different aspects of 4G which includes its features, its proposed architecture , key technological enabler, its benefits over existing wireless communication system, present key challenges and point to some proposed solutions.

Keywords: *Mobile system, Communication, Fourth Generation (4G), MIMO, SDR*

1. INTRODUCTION

Mobile systems focus on seamlessly integrating the existing wireless technologies including GSM, wireless LAN, and Bluetooth. 4G systems supports comprehensive and personalized services, providing stable system performance and quality service [1] . 4G is a Mobile multimedia, anytime anywhere, Global mobility support, integrated wireless solution, and customized personal service network system [2]. 4G is used broadly to include several types of broadband wireless access communication systems along with cellular telephone systems.

A 4G cellular system must have target peak data rates of up to approximately 100 Mbit/s for high mobility such as mobile access and up to approximately 1 Gbit/s for low mobility such as nomadic/local wireless access, according to the International Telecommunication Union[ITU] requirements. Scalable bandwidths up to at least 40 MHz should be provided. A 4G system is expected to provide a comprehensive and secure all-IP based solution where facilities such as IP telephony, ultra-broadband Internet access, gaming services and High Definition Television (HDTV) streamed multimedia may be provided to users.

In 4G networks, users joining the network via add mobile routers to the network infrastructure. Network capacity and coverage is dynamically shifted to accommodate changing user patterns.

Wherever the concentration of people is more in one area, additional routes are created, thus enabling additional access to network capacity in terms of QoS. This permits the network to dynamically and automatically balance capacity and increase network utilization. The network is currently used social networking. The following part of the paper is deals with social networking and its technological issues.

2. MOBILE COMMUNICATIONS REVIEW

The history and status of mobile communications are shortly listed in the following, together with the respective evaluations on the chief contributions.

a) Traditionally, wireless systems were considered as an auxiliary approach that was used in regions where it was difficult to build a connection by wireline.

b) 1G was based on analogy technique and deployed in the 1980s. It built the basic structure of mobile communications and solved many fundamental problems, e.g. cellular architecture adopting, multiplexing frequency band, roaming across domain, non-interrupted communication in mobile circumstances, etc. Speech chat was the only service of 1G.

c) 2G was based on digital signal processing techniques and regarded as a revolution from analogy to digital technology, which has gained tremendous success during 1990s with GSM as the representative. It introduced a new variant of communication called Short Message Service (SMS) or text messaging, Multimedia Messaging Services (MMS), General Packet Radio Service (GPRS), Wireless Application Protocol (WAP), Enhanced Data Rates for GSM Evolution (EDGE), and Internet services.[4] [5] The utilization of SIM (Subscriber Identity Module) cards and support capabilities for a large number of users were 2G's main contributions

d) 2.5G extended the 2G with data service and packet switching methods, and it was regarded as 3G services for 2Gnetworks. Under the same networks with 2G, 2.5G brought the Internet into mobile personal communications. This was a revolutionary concept leading to hybrid communications.

e) The third generation (3G) mobile broadband data services came with several incremental improvements in radio technology and command-and-control software. Radio advancements of 3G are classified as antenna techniques or coding/modulation schemes. Several new radio techniques are employed to achieve high rates and low latencies. They include Space Division Multiplexing via Multiple Input/Multiple Output (MIMO), Space Time Coding (STC) using higher order of modulation, and encoding schemes, sophisticated beam forming, beam directionality control, and inter-cell interference mitigation.[6]

3. ADVANTAGES OF 4G

The vision which considers 4G as an extension to 3G cellular services is called as *the linear 4G vision* [7]. But the extent of 4G capabilities goes beyond the cellular services. Envisioning 4G as high speed delivery of services via the most efficient network available from the pool of wireless networks is called as the *concurrent 4G vision* [7].

One of the major reasons of 3G being unable to repeat the success story of 2G was the provision of only few additional services over 2G. It was not encouraging enough for the customer's to change their equipments. Paper [7] suggests a user-centric approach for the design of 4G to avoid mismatch between the user's expectations and the services provided by 4G. Using the discussion in paper [7- 10], features of 4G which cater to the end-user's expectations and the problems of the current generation networks can be listed as follows:

3.1 User friendliness

4G aims at providing myriad of services to the end users at high speed. The applications developed to avail these services should be highly user friendly minimizing the interaction between the application and the user. For example, integration of speech recognition technology in the user interfaces

would ease the use of the applications for every layman.

3.2 User personalization

High data transfer rates and ubiquitous coverage of 4G networks would provide users access to large repository of data and services. Users should have flexibility to filter these data and services as per his preferences by configuring the operational mode of their devices, so that he can preselect the service features he wants to use. Figure 1 illustrates elements and techniques to support the adaptability of the 4G domain.

Figure 1: 4G will allow everyone to access the Internet from everywhere using almost any wireless device.

3.3 Terminal and Network heterogeneity

Terminal heterogeneity refers to the different types of terminals in terms of the size, weight, display features, power consumption, etc. Network heterogeneity means the different types of access networks like *WiMAX*, *Wi-Fi* (Wireless Fidelity), *UMTS* (Universal Mobile Telecommunications System) and so forth which differ in their coverage area, data rate, latency and data loss rate.

Each of these terminals and services cater to different user requirements. In 4G, all these terminals and networks will provide common services independent of their capabilities. This is also called as *service personalization*.

3.4 High Performance

Low transfer rates of 3G restrict the user's ability to take advantage of the rich multimedia contents across the wireless networks. 4G is expected to provide wireless download speeds of about 1Gbps in local area network (LAN) and 100 Mbps in wide area network (WAN), about 260 times greater than the 3G wireless networks.

3.5 Interoperability

Multiple standards of 3G restrict the user's mobility and interoperation across different networks. 4G targets at providing a unified global standard which will facilitate global mobility and service portability. In other words, end user can subscribe to different services from different service providers using the same mobile device.

3.6 Intelligent Networking

3G is based primarily on cell or base station WAN design. 4G aims at building hybrid networks utilizing both the Wireless LAN concept and WAN design. Thus, the world would have base stations everywhere providing ubiquitous network coverage to users at high speed. For example, a user walking on road is browsing internet using *GPRS* (General Packet Radio Service-WAN design). The moment he enters a mall with Wi-Fi (LAN design), seamless hand-over from GPRS to Wi-Fi would take place without the user's knowledge.

3.7 Network Convergence

Network convergence is the efficient coexistence of multimedia, voice and data communication within a single network. [10] Currently the telecommunication environment is divided into wireless and fixed line communication. To avail these different kinds of services, the end user require different devices such as cellular phones, fixed line phones, laptops and PDA's. Once the fixed mobile convergence is in place in 4G, the distinction between these services will disappear. The current 3G technology is not able to capture the market share as done by the fixed line services partly because of its low bit rates of 384kbps and because of the high costs associated with these services. But with the emergence of 4G aiming at global integrated IP based network, the wireless sector will be able to match the fixed line sectors in terms of both costs and speed. 4G will lead to convergence in terms of both devices and services. Thus, handset capabilities, MP3, camera, mobile broadband services would be made available in a single device.

Service convergence will result from availability of telecommunication and internet on a single platform. This would force the fixed line sector to jump in the competitive wireless market. In response, the wireless operators will also jump into the fixed line sector. Thus slowly the boundaries between these markets will disappear. Thus, the end user will benefit from one business providing variety of services. He will experience high quality service at affordable prices. Thus fixed mobile convergence will act as a catalyst for stimulating markets to come up with new innovative and cost effective ideas.

3.8 Scalability

Scalability in mobile networks is the ability to handle the increasing numbers of users and services. 4G will use IPv6 addressing scheme which will support large number of wireless devices eliminating the need for Network address translation (NAT). NAT is technique of sharing limited number of addresses among large number of devices. The huge expanse of current internet world signifies the scalability support of IP. Thus, the use of IP as core network layer will make 4G easily scalable.

3.9 Lower power consumption

Battery technology has not been able to keep pace with the growing telecom industry. 2G devices required one battery while 3G required two batteries. Battery drain is a persistent problem of wireless devices. 4G aims at breaking this directly proportional rule. Shorter communication links is one of the few solutions proposed to cater to this requirement.

3.10 Low costs

4G is designed to be spectrally efficient with no requirement to buy costly extra spectrum. It is not development of a completely new system rather built on the top of the existing networks. 4G will also support backward compatibility with 2G and 3G devices. All these factors will make 4G much cheaper than the current generation networks.

4. 4G NETWORK ARCHITECTURE

Figure 2 shows the widely accepted 4G network structure with IP as the core network used for communication; integrating the 2G, 3G and 4G technologies using a convergence layer [9].

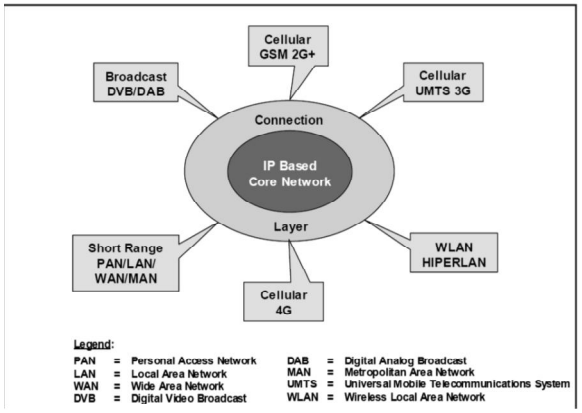
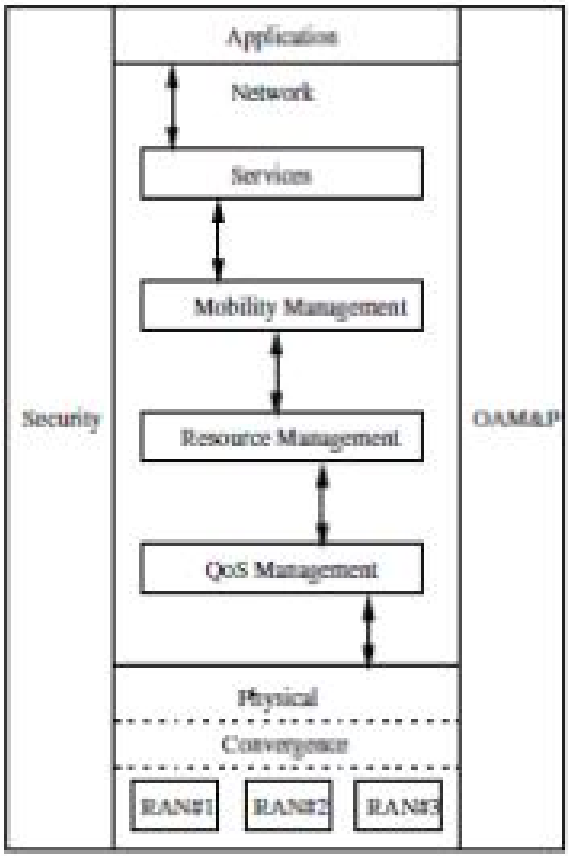


Figure 2 shows the proposed layered/level Architecture of 4G network elucidated in [6].

This architecture fulfills the basic requirement of servicing the standalone and mobile subscribers on an "*anytime, anywhere, anyhow*" basis in dynamic network conditions. The architecture is based on Internet Protocol version 6 (IPV6) which operates at the transport layer enabling seamless communication across various heterogeneous networks and based on the key factors such as mobility, Quality of Service (QoS) and efficient resource management schemes. The functionalities provided by each layer and module can be described as follows:



4.1 Application

This layer is composed of various third party applications which provide value added services to its subscribers.

4.2 Network

This layer consists of various sub layers described as follows:Services

This layer manages the interaction between various value-added services and networks.

4.2.1 Mobility Management

This layer provides quality and uniform services to the mobile/stationary terminal across various heterogeneous networks. It provides features of low handover latency

and packet loss during the provision of real-time and non-real time services to the end user moving across different networks. To achieve this, it performs tasks such as binding update (updating the care-off address of the mobile user), location management, common control signaling (signaling required to perform wireless network discovery), address assignment, handover control mechanism and so forth.

4.2.2 Resource Management

This layer incorporates the functionalities of allocation, de-allocation and reallocation of the network resources which are acquired during the communication sessions within the same or different network domains. This activity is performed during or before the communication activity. This layer also performs the task of congestion control, packet scheduling and packet classification.

4.2.3 Quality of service (QoS) management

This layer provides best optimal utilization of the available resources. In scenarios where the network resources are limited it provides an option to the applications to choose between high overall throughput and low end-to-end delay. It provides the best trade-off mechanisms depending on the application's preference. It encompasses several activities such as link utilization control, bandwidth control and so forth.

4.3 Physical

This layer consist of the core IPV6 network of 4G and other heterogeneous access networks such as GSM (Global System for Mobile communications), CDMA(Code Division Multiple Access) and WLAN in their physical view. This layer is composed of two sub-layers namely:

4.3.1 Convergence layer

This layer provides common control signaling mechanism across the core and other heterogeneous networks at the physical level. It also allows different radio access networks to transparently use the independent network services such as mobility management, resource management and QoS management.

4.3.2 Different RAN

This layer consists of several radio access networks communicating with each other at the physical level.

4.4 Operation, Administration, Maintenance and Provisioning

This layer spans across all the layers of the network architecture and provides the functionalities of network controlling, network monitoring and fault detection. It also maintains the repudiation between various services and resources of several heterogeneous and core networks.

4.5 Security

This layer also branches across all the layers of the 4G network architecture which perform the function of authentication, authorization, encryption, establishment and implementation of service policy agreement between the various vendors.

5. TECHNOLOGY USED IN 4G COMMUNICATION SYSTEM

There are some components which makes the successful 4G systems they are:

a) OFDMA
b) MIMO
c) IPv6.0
d) Spectral efficiency of 4G
e) SDR(Software Defined Ratio)
f) Smart antennas

a. OFDMA(Orthogonal Frequency Demux):

OFDMA can be used for the downlink transmission (signal transmission from the base station to mobile terminal) of the symbols for achieving high spectral efficiency. It provides high performance on full bandwidth usage.

It is a channel allocation scheme based on the orthogonal frequency division multiplexing technique that splits the data to be transmitted along the orthogonal narrowband carriers well spaced by frequency. The technique used for splitting the data is Inverse Fast Fourier Transform (IIFT) which incorporates the advantage of transmitting the data at a higher rate. The introduction of a cyclic prefix (CP) in terms of guard interval consists of repetition of the last part of the symbol at the beginning of each symbol transmitted. This avoids interference between the various symbols and the carriers if the CP interval is longer than the delay caused by the interferences of the channel. This improves the robustness of the technology used for the multipath transmission. The use of narrowband subcarrier is to get a channel which is constant for each sub-band (input symbol broken down number of smaller bands). This avoids synchronization problems at the receiver side during the symbol transmission through the channel. In order to get high spectral efficient system, overlapping between the mutually orthogonal subcarrier is allowed.

OFDMA is compatible with other technologies such as Multiple Input Multiple Output and smart antennas. OFDM not only improves the performance of the physical layer but also adds to the improvement of the Data Link Layer. It facilitates the optimization between various layers of network for usage of radio link from multiple radios.

OFDMA is currently applied on various wireless and wire line standards such as Wi-Fi, Wireless LAN, Ultra Wideband (UWB), Wireless PAN, WiMAX, WiBro, HiperMAN, Wireless MAN, 3GPP UMTS & 3GPP@ LTE (Long-Term Evolution).

b. Multiple-Input and Multiple-Output (MIMO)

To improve the communication performance between sender and receiver, the multiple antennas are used at both transmitter and receiver end. The signal transmitted by m antennas and signal received by n antennas and the processing of the received signal may produce significant performance improvement such as ***range***, ***quality of received signal*** and ***spectrum efficiency***.

c. Software Defined Radio (SDR)

SDR is a radio communication system implemented as software on the personal computer or embedded devices. It scans the available networks and then reconfigures itself for the selected network by downloading the software specific to that network. It is used for implementation of the multimodal, multi-band, multi-standard user terminals and base stations which allows accessibility across various wireless and wireline heterogeneous networks. There are several advantages of SDR such as flexibility in network expansion i.e. operator can expands its network infrastructure by adding few modems to base station transceiver system. It reduces the cost for development of multimodal, multiband and multi-standard user equipments. This will benefit both the end users and the service providers. The current SDR technology is not capable of supporting the multiple networks. It should be enhanced to support multiple networks.

d. IPv6.0:
4G wireless technology will be using mobile IPv6 which allows assigning more number of addresses than IPv4. In IPv6 each device have ***own IP address***. User can keep their IP address even if user changes the access point.

e. Smart Antennas:
There are two types of smart antennas which are switched beam smart antennas and adaptive array smart antennas. Switched beam systems have several available fixed beam patterns which help in making decisions as to which beam to access at any given point of time based on the requirements of the system. While adaptive arrays allow the antenna to steer the beam to any direction of interest while simultaneously nulling interfering signals.

6. CHALLENGES

6.1 Security and Privacy

In the development of 4G Networks, security measures must be established that enable data transmission to be as safe as possible. Specifically, "The 4G core addresses mobility, security, and QoS through reuse of existing mechanisms while still trying to work on some mobility and handover issues" [11]. Therefore, it is necessary for the organization to develop an effective series of tools that support maximum 4G security measures as a means of protecting data that is transmitted across the network from hackers and other security violations. Because of the nature of the 4G network, there is an increased likelihood of security attacks, and therefore, multiple levels of security, including increased requirements for authentication, will be necessary to protect data and information that is transmitted across the network [11].
One of the main goals of G4 networks is to blanket very wide geographic area with seamless service. Obviously, smaller local area networks will run different operating systems. The heterogeneity of these wireless networks exchanging different types of data complicates the security and privacy issues. Furthermore, the encryption and decryption methods being used for 3G networks are not appropriate for 4G networks as new devices and services are introduced for the first time in 4G networks. To overcome these security and privacy issues, two approaches can be followed. The first is to modify the existing security and privacy methods so that they will be applicable to heterogeneous 4G networks. Another approach is to develop new dynamic reconfigurable, adaptive, and lightweight mechanisms whenever the currently utilized methods cannot be adapted to 4G networks [12].

6.2 Quality of Service

With respect to network quality, many telecommunications providers are promising that there will be enhanced connectivity, and the quality of data that is transmitted across the network will be of the highest possible quality, as in the case of Ericsson's 4G Network for TeliaSonera [13]. The company promises that "The new 4G network will do for broadband what mobile telephony did for voice. With real-time performance, and about 10 times higher data rates compared to today's mobile broadband networks, consumers can always be connected, even on the move" [13]. As a result, it is important for providers to develop an effective approach to the 4G Network that will enhance quality, provide effective security measures, and will ensure that all users are provided with extensive alternatives for downloading video, music, and picture files without delays.
The main challenge that 4G networks are facing is integrating non-IP-based and IP-based devices. It is known that devices that are not IP address based are generally used for services such as VoIP. On the other

hand, devices that are IP address based are used for data delivery. 4G networks will serve both types of devices. Consequently, integrating the mechanisms of providing services to both non-IP-based as well as IP-based devices is one of key challenges 4G networks have to address [14, 15].

6.3 Complex Architecture

6.3.1 Multimode End-User Terminals

To reduce operating costs, devices that operate on 4G networks should have the capability to operate in different networks. This will not only reduce the operating cost but will also simplify design problems and will reduce power consumption. However, accessing different mobile and wireless networks simultaneously is one of the major issues 4G networks have been addressing. One mechanism that has been proposed to handle this problem is termed "multi-mode devices". This mechanism can be achieved through a software radio that allows the end-user device to adapt itself to various wireless interfaces of the networks. Figure 3 shows an example of such solution.

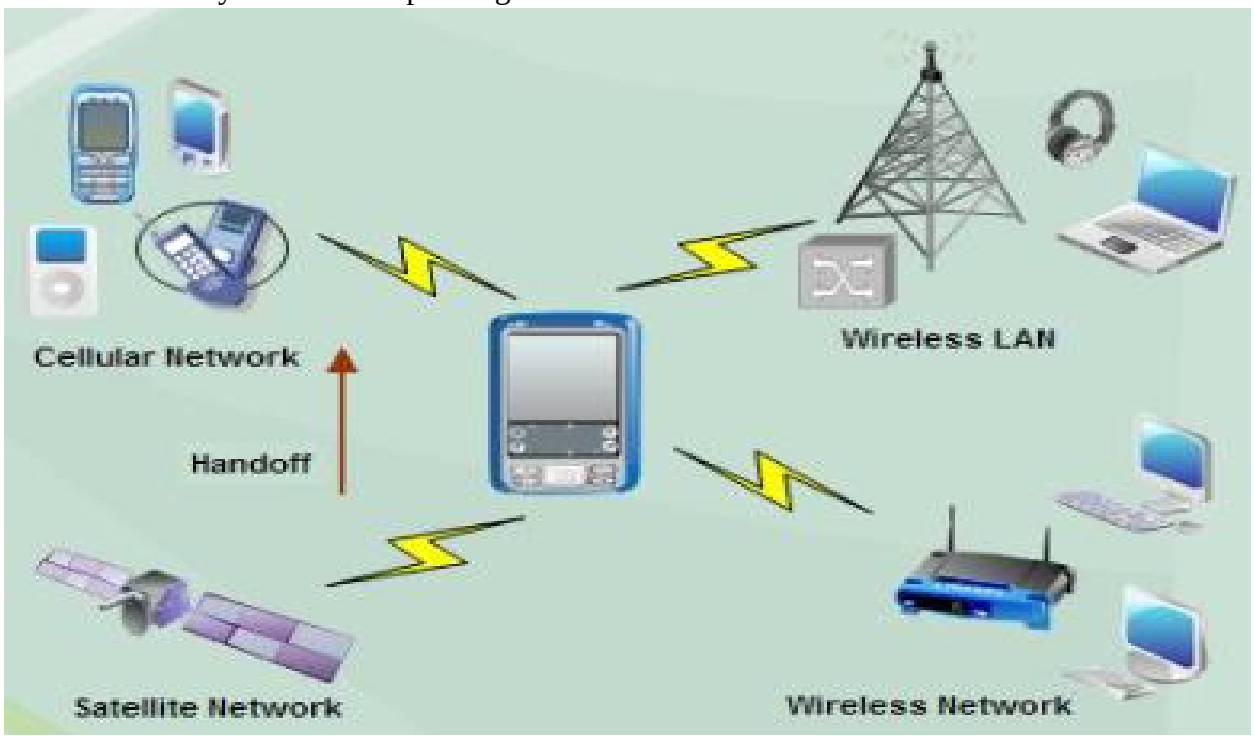


Figure 3: Accessing multiple networks and services through multi-mode software

6.3.2 System Discovery and Selection

Due to the heterogeneity of 4G networks, wireless devices have to process signals sent from different systems, discover available services, and connect to appropriate service providers. Various service providers have their own protocols which can be incompatible with each other as well as with the user's device. This issue may complicate the process of selecting the most appropriate technology based on the time, place and service provided, and thus, may affect the Quality of service provided to the end user.

One solution to resolve this issue is called "System-initiated discoveries". This mechanism allows automatic download of software modules based on the wireless system the user is connected to [16]. Another approach to handle this problem is based overlay networks. In such case, the

end-user device is connected to different networks through an overlay network. The overlay network performs all necessary tasks such as protocol translation and Quality of service negotiation as depicted in Figure 4.

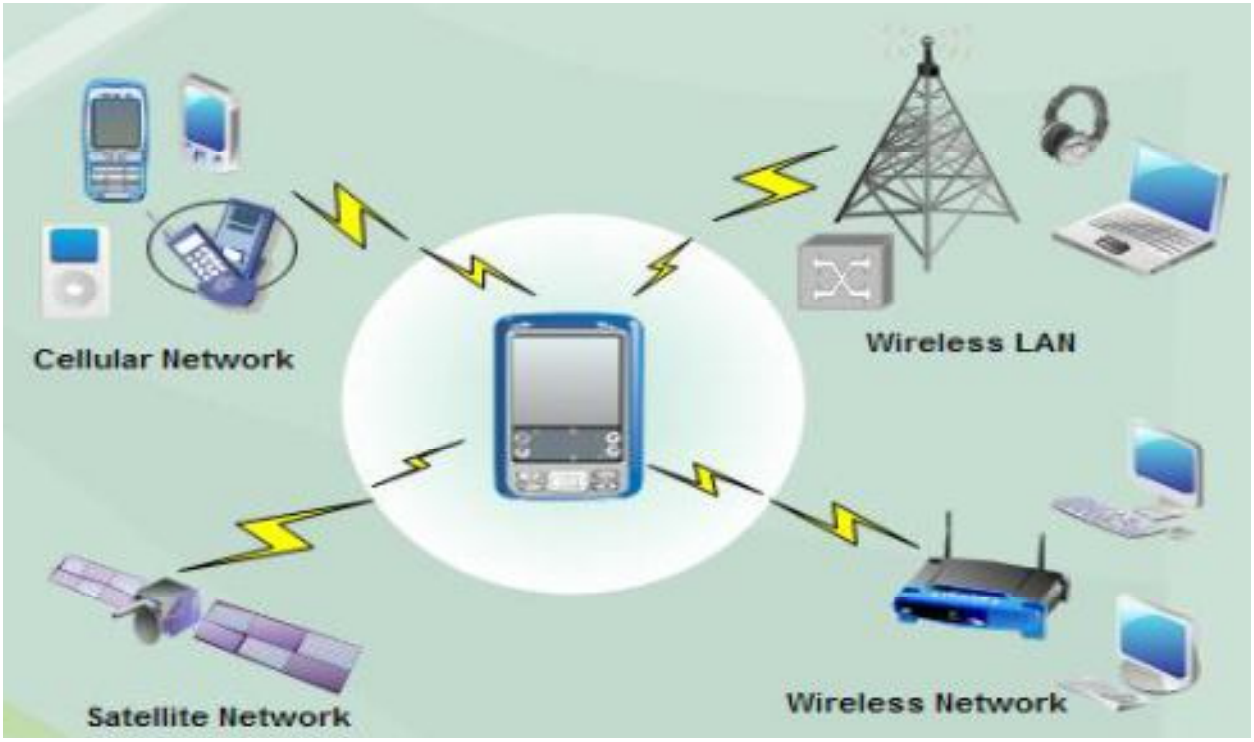


Figure 4: Automatic system discovery is one of the features provided by 4G networks.

6.3.3 Service and Billing

Managing user accounts and billing them has become much more complicated with 4G networks. This is mainly due to heterogeneity of 4G networks and the frequent interaction of service providers. The research community addressed this concern and proposed several frameworks to handle the customers' billing and user account information [17, 18].

7. CONCLUSION

This paper presents 4G wireless communication. 4G wireless networks not only enable more efficient, scalable, and reliable wireless services but also provides wider variety of services. The benefits to service providers and end users drive the adoption of 3G services that, in turn, lead to the demand for even more advanced services. The realization of 4G tears down the wall between wireless and wireline services, a challenging endeavor. We believe, however, that future research will overcome these challenges and integrate newly developed services to 4G networks making them available to everyone, anytime and everywhere.

REFERENCES

[1] Suk Yu Hui Kai Hau Yeung , City Univ. of Hong Kong, China; Challenges in the migration to 4G mobile ystems Communications Magazine, IEEE Volume: 41, Issue: 12 ISSN: 0163- 6804 Dec. 2003.

[2] Moray Rumney, "IMT-Advanced: 4G Wireless Takes Shape in an Olympic Year", Agilent Measurement Journal, September 2008.

[4] Brookes, T. 2012. A brief history of mobile phones. Retrieved from http://www.makeuseof.com/tag/history-mobile-phones/

[5] Gupta, A. 2012. Introduction and types of wireless technologies. Retrieved from http://www.bukisa.com/articles/743302_introduction-and-types-of-wireless-technologies

[6] Badoi, C. I. 2011. Tellabs Operations, 4G. The what, why and when. Retrieved from www.tellabs.com/4g/whatwhywhen.pdf

[7] Frattasi, S.; Fathi, H.; Fitzek, F.H.P.; Katz, M.D.;Prasad, R. Defining 4G Technology from the User's Perspective. IEEE Volume 20, Issue 1, Jan.-Feb. 2006,Page(s):35 – 41.

[8] Santhi, K.R.; Srivastava, V.K. ; SenthilKumaran,G.; Butare, A. Goals of True Broad band's Wireless Next Wave (4G-5G). *Vehicular Technology Conference, 2003.VTC 2003-Fall. 2003 IEEE 58th*, Volume 4, Oct.2003, Pages(s): 2317-2321.

[9] A. H. Khan, M. A. Qadeer, J. A. Ansari and S.Waheed. 4G as a Next Generation Wireless Network. *Future Computer and Communication, 2009. ICFCC 2009.International Conference,* April 2009, Page(s):334 - 338

[10] Jinsung Choi. 4G, Solution for Convergence?.*Microwave Symposium Digest, 2006. IEEE MTT-S International*, June 2006 , Page(s):843 - 846

[11] E. Buracchini, "The Software Radio Concept," IEEE Commun. Mag., vol. 38, no. 9, 2000, pp. 138–43.

[12] N. Montavont and T. Noel, "Handover Management for Mobile Nodes in IPv6 Networks," IEEE Commun. Mag., vol. 40, no. 8, Aug. 2002, pp. 38–43.

[13] J. Fleck, "A Distributed Near Real-time Billing Environment," Telecommun. Info. Net. Architecture, 1999, pp. 142–48.

[14] P. Taylor, AT&T to roll out 4G network, 2009.

[15] D. Tipper et al., "Providing Fault Tolerance in Wireless Access Networks," IEEE Commun. Mag., vol. 40, no. 1, Jan. 2002, pp. 58–64.

[16] A. Lyle, Clear, first 4G network launched, 2009.

[17] F. Ghys and A. Vaaraniemi, "Component-based Charging in a Next-generation Multimedia Network," IEEE Commun. Mag., vol. 41, no. 1, Jan. 2003, pp. 99–102.

[18] S. Higgenbotham, Countdown to 4G: who's doing what, when, 2008.

[19] 4G Wireless Networks: Opportunities and Challenges.

Samson Busuyi Akintoye received the B.Tech. degree in Industrial Mathematics from Federal University of Technology, Akure, Nigeria in 2002. He received his M.Sc. degree in Computer Science from University of Ibadan, Ibadan, Nigeria in 2006. Currently, he is pursuing his Ph.D. degree in Computer Science from Babcock University, Ilishan-Remo, Nigeria.