5G Next Generation Wireless Network Concept

Neslihan Ademi

neslihan@ibu.edu.mk

International Balkan University, Faculty of Engineering-Skopje, North Macedonia

ABSTRACT

Mobile communications and wireless networks are developing at an outstanding speed, with evidences of significant growth in the areas of mobile subscribers and terminals, mobile and wireless access networks and mobile services and applications. Mobility management, network selection, handover mechanisms and QoS control in next generation heterogeneous networks are still open research issues and all of them depended to each other. In this paper, different mobility solutions in heterogeneous wireless networks are over-viewed and classified according to their layer. QoS support for mobility, network selection and handover mechanisms are also reviewed to have complete picture of next generation networks.

Keywords: ***5G, next generation networks, QoS, heterogeneous networks, mobility, wireless networks***

INTRODUCTION

With the fast-growing Internet technology in all-IP network architecture, the wireless communication systems offer mobile users the convenience to access information around the world from anywhere and at anytime. Recent mobile devices are integrated with multiple network interfaces (such as WLAN, Bluetooth, 3G adapters) to connect different radio access technologies (RATs). Mobile communications and wireless networks are developing at an outstanding speed, with evidences of significant growth in the areas of mobile subscribers and terminals, mobile and wireless access networks and mobile services and applications. Second generation (2G) mobile systems which was carrying speech and low-bit-rate data were very successful in the previous decade. 3G systems were designed to provide higher-data-rate services to give users chance for downloading real-time multimedia applications also. At the same period, many different standards on wireless networks have been improved: 802.11 Wireless Local Area Networks (WLAN), 802.16 Wireless Metropolitan Area Networks (WMAN) and Wireless Personal Area Networks (WPAN) such as Bluetooth. All these systems were designed independently, targeting different service types, data rates and users. All of them have different merits and shortcomings but there is no single system that is good enough to replace all of the other technologies.

Currently researchers from all around the world are developing frameworks for 4G mobile networks and systems. Some of the researchers still put effort into developing new radio interfaces and technologies for 4G mobile systems, but some of them believe that integrating the existing systems into one open platform is a more feasible option. There is a need to provide the best possible IP performance over wireless links, including legacy systems and future systems. To perform such a concept an open wireless architecture (OWA) is proposed [1]. OWA is targeted to provide open baseband processing platform to support different existing and future wireless standards with open interface parameters and baseband management systems. OWA proposes a solution to the interworking of different wireless technologies at Physical Layer and Data Link Layer (MAC). 5G wireless technologies are seem to be based on OWA concept for these two layers [2].

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From the user's side one of the key features of next generation wireless and mobile technologies is high usability: anytime, anywhere and with any technology. The user should have possibility to use all wireless technologies in the range using his or her personal settings. According to [2], 5G wireless mobile internet network is a completed wireless communication with almost no limitation. 5G networks will be a combination of all existing and future wireless technologies and it is seen to be user-centric. 5G terminals will have access to different wireless technologies at the same time and will make the final choice among different wireless/mobile network provider for a given service.

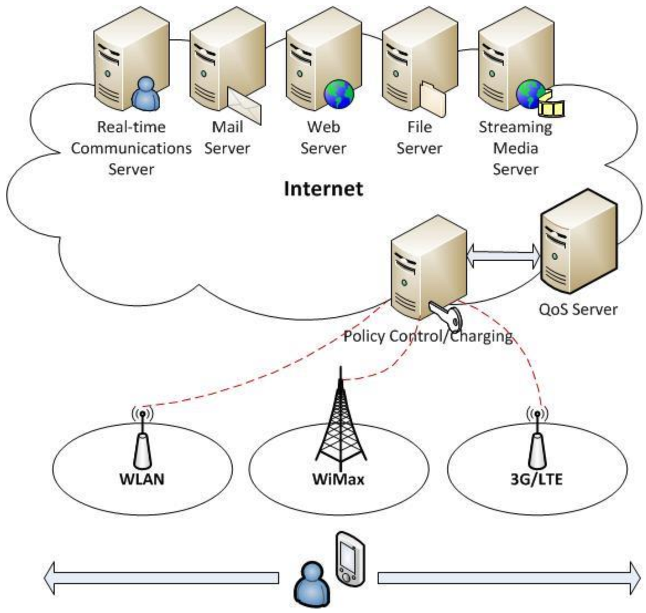

Fig. 1 Next Generation Mobile Networks

MOBILITY IN NEXT GENERATION NETWORKS

Mobility in next generation networks requires new level of mobility support as compared to traditional mobility. Existing mobility protocols and mechanisms does not appropriately solve the demands of future communication scenarios, because in next generation networks users and terminals will have mobile connections to different networks simultaneously in different standards. Future wireless systems have a hierarchical architecture where different access networks have dramatically different coverage areas. Mobility management techniques should allow mobile users to roam among multiple wireless networks in a manner that is completely transparent to applications and disrupts connectivity as little as possible. Moreover, in wireless overlay networks the choice of the “best” network for location and handoff management places a new challenge because different overlay levels may have widely varying characteristics.

Internet technology is developing in an all-IP network architecture. There are two basic approaches to provide IP-based mobility management: network-based mobility management and client-based mobility management. [3]

Network-based solutions require existing network deployments to be upgraded and they have an operator centric approach to mobility. In this approach, each Radio Access Network (RAN) must be part of the same network operators’ infrastructure. This difficulties lead researchers to begin looking at alternative approaches to host mobility. Endpoint based (user-centric) solutions require no network infrastructure modifications. So endpoint centric handover solutions can be developed by shifting the complexity out of the network and into the mobile devices. [4]

There are many research work done in the area of IP mobility, and many different approaches are proposed. The most common one is Mobile IP (MIP) [5]. In MIP approach each Mobile Node (MN) has two IP addresses: static address and Care of Address (CoA). Static address-home address presents at the home network and Care of Address (CoA) changes for each foreign network. MIP allows MN to be reachable through its home address by maintaining bindings between the two addresses. For this purpose, MIP requires addition of a Home Agent (HA) in the resident network and a Foreign Agent (FA) in the visited network. FA assigns the IP address that will serve as the MNs CoA and to inform the HA about the MNs new IP address. A tunnel is established between the FA and the MNs home network so that the MN is reachable via its HA. This causes increased link delay and problems with scalability. The major drawback in using MIP is the required large scale deployment by adding new network nodes.

An improvement to MIP; MIPv6 is presented in [6]. MIPv6 does not require special routers like FA and operates without support from the local router, which means it requires less modification to the network infrastructure in comparison to MIPv4.

In [4] also other proposed network based handover solutions are given i.e. Fast handovers for MIPv6 (FHMIP), Hierarchical Mobile IP (HMIP), Cellular IP (CIP), Handoff-Aware Wireless Access Internet Infrastructure (HAWAII), Proxy MIPv6 (PMIPv6).

Proxy Mobile IPv6 is also proposed for 3GPP EPC mobility and [3] provides an overview of 3GPP Evolved Packet Core (EPC) specifications that use a network-based mobility mechanisms based on Proxy Mobile IPv6 and interaction of PMIPv6 with QoS support. In this approach QoS information is provided by Session Initiation Protocol (SIP) server in IP Multimedia Subsystem (IMS).

On the other hand, end-to-end solutions move intelligence from the network to the mobile terminals having the advantages of requiring fewer or no network modifications. Recent user equipments are developing and have more powerful processing units and more memory compared to previous decade. This means they will be capable to process algorithms for handover, network selection- one or more network at the same time and to store QoS history together with other parameters.

In [4] some end-to-end solutions are also listed: Transmission Control Protocol (TCP) Migrate is an end-to-end internet host mobility approach. It focuses on the issue of continuing an existing TCP session without having to re-establish the TCP connection. A new option is proposed in SYN packets that identifies the packet as part of a previous TCP connection allowing a MN to restart an open TCP connection from a new point of attachment. The advantage of this scheme is that it does not require any network infrastructure modifications, only the TCP stack of each node need to be upgraded. However, since this mobility solution only works with TCP and can suffer from significant handover delays it is unsuitable for real time applications such as VoIP. Another transport layer based approach is Mobile SCTP (MSCTP). MSCTP leverages the ability of SCTP to have multiple IP addresses per association. MSCTP utilises a feature of SCTP called the Dynamic Address Reconfiguration (DAR) extension which allows a MN to dynamically switch between available access networks thereby effecting seamless handovers. MSCTP suggests the use of Session Initiation Protocol (SIP) or MIP to deal with location management but focuses on using MIP. Although only the MN needs to be MIP enabled, MSCTP still requires network modifications to implement a HA. Consequently, it suffers from the same network modification requirements problems as MIP. Also, a handover decision is made simply based on the RSS at the MN and does not consider any QoS metrics.

SIGMA (Seamless IP diversity based Generalized Mobility Architecture) [7] is a transport layer mobility mechanism based on SCTP, similar to MSCTP. It was designed to be an end-to-end handover solution which does not require any infrastructure support. SIGMA utilises IP diversity and the DAR extension to SCTP to perform seamless handovers for mobile hosts between wireless networks. In [7] SIGMA is also compared to MIPv6, HMIPv6 and FHMIPv6 in terms of handover latency, throughput, packet loss rate, and network friendliness and shown that SIGMA has a lower handover latency, lower packet loss rate and higher throughput than MIPv6 enhancements in simulation results.

Multiple Address Service for Transport (MAST) defines a layer between IP and transport layers supporting association of multiple IP addresses during the life of any transport instantiation. It operates only in the end systems and affects only participating hosts. So it does not require modifications to the Internet infrastructure and any host's IP or transport modules. [8]

Host Identity Protocol (HIP) [9] is an extension that allows multi-homed HIP hosts to use multiple access networks simultaneously. This extension defines how to identify data flow and how to route them based on higher level policies and specifically address the issue of the return path by transferring the policies to the peer. HIP separates identifier from locator at the network layer and adds host identity layer in between IP and transport layers.

Mobility management solutions can also be classified according to layers applied on:

- Network layer – Mobile IP
- Transport Layer - TCP Extensions, MSCTP (Stream control transmission protocol)
- Application Layer – SIP (Session Initiation Protocol)
- Providing Mobility Support in a New Layer – HIP (Host Identity Protocol), MAST (Multiple Address Service for Transport) and MOBIKE(IKEv2 Mobility and Multihoming)
- Cross-Layer – ECHO (Endpoint centric handover)

In an early study [10], the strengths and weaknesses of implementing mobility at three different layers of TCP/IP stack is discussed; as the the best layer candidate to accommodate Internet mobility, transport layer is suggested. Also it is noted that there should be more collaboration between layers to avoid confliction and inefficiency.

In terms of mobility and efficient handover decision, all layers should be monitored and controlled. In this regard, mobility management and handover decision should be performed in a cross-layer framework.

The proposed cross-layer solutions show that cooperation between different layers such as network and link layers is able to improve the performance of mobility management in IP-based heterogeneous communication environment. Information from the link layer, such as signal strength and velocity of mobile terminals, may help the decision making of mobility management techniques at the network layer.

CROSS-LAYER METRICS

Using a cross-layer approach handover mechanism can utilise information from each of the layers in the protocol stack and make more informed handover decisions.

A new proposed cross layer approach ECHO (Endpoint centric handover) uses the following parameters from each layer [4]:

- Physical layer – depending on the underlying access technology, physical layer parameters such as RSS and Signal to Noise Ratio (SNR) are monitored. This enables the MN to predict when a network will become unavailable and offers the ability to compare the physical layer parameters from each of the available access networks. Also, the physical layer is used to proactively scan for available access networks.
- Network layer – on detection of a newly available access network, the network layer is used to obtain an IP address on that network.
- Transport layer – once a new IP address is obtained SCTP adds the new IP to the association. Round Trip Time (RTT) metrics for that network can then be obtained at the transport layer.
- Application layer – the application layer is used to calculate loss and jitter values for each available access network.

IEEE 802.21 standard framework describes the interworking within IEEE 802 systems (e.g., IEEE 802.11 and IEEE 802.16e) and between IEEE 802 and non-IEEE 802 systems (e.g., cellular networks). Media Independent Handover (MIH) defines a technology-independent abstraction layer able to provide a common interface to upper layers, thus hiding technology specific primitives [11]. It proposes cross-layer mobility management architecture based on IEEE 802.21. The media-independent handover function (MIHF) is placed between the network and data link layers. Remote MIH events and commands may be received from and sent to other MIH stacks respectively. So IEEE 802.21 enables co-operative handover decision making supporting both terminal-based and network-based mobility management schemes.

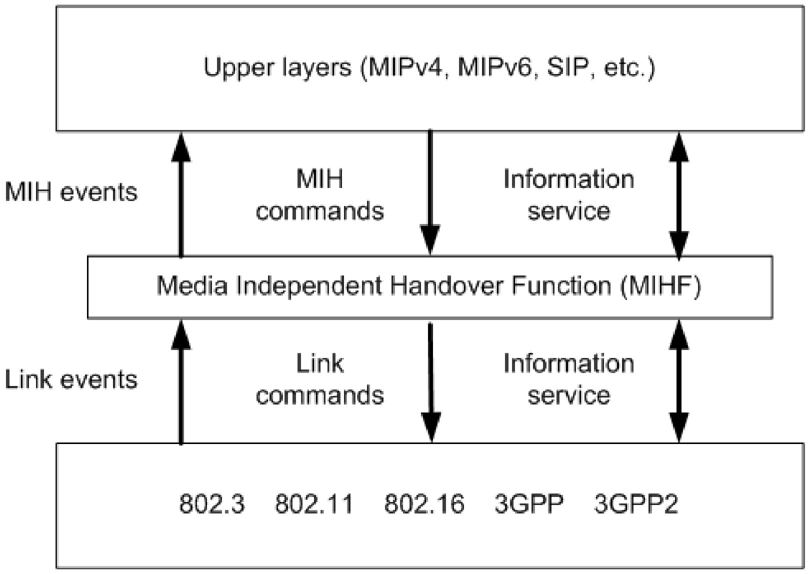

Fig. 2 Basic Organization of MIH Services [11]

The most notable benefit of using the proposed architecture is that it is fully backward compatible since the standard Socket API remains unchanged. Legacy applications may run as if they were executed in a fixed environment, while the proposed solution also enables mobility-aware applications to handle mobility in application-specific ways [11].

QUALITY OF SERVICE / QoS SUPPORT IN MOBILITY MANAGEMENT

One of the most important technical features of the networks available through the mobile terminal is the offered Quality of Service (QoS). QoS is defined in a different way for each wireless technology (802.11 WLAN, 802.16 WMAN, 3G, 4G etc.). Next Generation all-IP-based wireless systems will provide guaranteed QoS to mobile terminals carrying multimedia applications, including best effort and real-time traffic. These applications have varying requirements which challenge the best effort service model of the original framework for IP. Bandwidth, throughput, timeliness, reliability, perceived quality, and costs are the foundations of QoS. QoS provisioning in a heterogeneous mobile computing environment introduces new problems to mobility management, such as location management for efficient access and timely service delivery, QoS negotiation during intersystem handoff, etc.

QoS control mechanisms can be classified as network-initiated or terminal-initiated. New trend in QoS control and support is user-centric approach allowing dynamic QoS adjustment in the terminal.

QoS control in the 3GPP Evolved Packet System (Release 8) is network initiated QoS control paradigm where the operator controls the service. The "bearer" is a central element of the EPS QoS concept and is the level of granularity for bearer-level QoS control. The network-initiated QoS control paradigm specified in EPS is a set of signaling procedures for managing bearers and controlling their QoS assigned by the network. The EPS QoS concept is class-based, where each bearer is assigned one and only one QoS class identifier by the network. An EPS bearer uniquely identifies packet flows that receive a common QoS treatment between the terminal and the gateway. A packet flow is defined by a five-tuple based packet filter, that is, the packet filters in the terminal (for uplink traffic) and the gateway (for downlink traffic) determine the packet flows associated with an EPS bearer. [13]

The EPS QoS concept is class-based, where each bearer is assigned one and only one QoS class identifier (QCI) by the network. The QCI is a scalar that is used within the access network as a reference to node-specific parameters that control packet-forwarding treatment (e.g., scheduling weights, admission thresholds, queue management thresholds, link-layer protocol configuration, etc.) and that were preconfigured by the operator owning the node (e.g., the LTE base station).Each standardized QCI is associated with standardized QCI characteristics. The characteristics describe the packet-forwarding treatment that the bearer traffic receives edge-to-edge between the terminal and the gateway in terms of bearer type (GBR or non-GBR), priority, packet delay budget, and packet-error-loss rate.[13]

NETWORK SELECTION

Networks selection technique plays a vital role in ensuring Quality of Service (QoS) in heterogeneous networks. Since the network and resource choice will made by the terminal, to provide users optimum network resources and bandwidths, novel network selection algorithms are needed. Various factors of the candidate networks need to be taken into account such as network characteristics, service type, user mobility, network condition, user preference and service cost.

[14] presents a novel multi-criteria network selection algorithm for always best connected service provisioning. It implements the selection algorithm at a middleware layer; this hiding both network cost computation and 4G scenario complexity from user and application layers. QoS parameters, user profile and cost preferences are considered dynamically during the network selection.

In [15] a novel intelligent algorithm M-RATS which works on the mobile terminal side is introduced and compared with different network selection algorithms, and shown that it provides best Radio Access Technology Selection by using naturally inspired algorithms. In this RAN selection scheme multi-criteria decision algorithm is supported by fuzzy logic controllers and genetic algorithm optimization to evaluate operator requirements, user requirements, QoS requirements and link conditions.

In the Third Generation Partnership Project (3GPP), Access Network Discovery and Selection Function (ANDSF) is being developed and provides inter-system mobility policies and access-network-specific information to the mobile nodes. [16]

To enable more than one access network selection simultaneously and coordinating different interfaces on the mobile terminal are also open issues in wireless heterogeneous networks.