

Performance Comparison of UMTS/WLAN Integrated Architectures with Dynamic Home Agent Assignments

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Abstract— Wireless local area networks (WLANs) are providing the most economical means of internet access. However, their access is very much limited. They can be deployed in a large scale by integrating them with cellular networks such as universal mobile telecommunication system (UMTS); general packet radio services (GPRS) etc. A seamless roaming between these two heterogeneous networks can be ensured through mobile IP. But the two networks don't have support towards mobile IP which requires the deployment of home agents and a protocol between the mobile nodes, home agents and foreign agents. Hence seamless roaming can be provided by incorporating Mobile IP support in WLAN networks. The cellular network requires the home agent placement and the appropriate home address to be assigned are the issues for supporting Mobile IP for heterogeneous roaming. If the mobiles use a home agent (HA) that is deployed in a UMTS network when roaming in a WLAN network, the UMTS network may get overloaded with WLAN traffic. The solution to this problem is to dynamically assign an HA in WLAN domain. Different architectures can be obtained by placing HA at different positions each having its own shortcomings, in which HA is placed between border router and GGSN that requires HA performing very high speed routing as fast as GPRS gateway signaling node (GGSN) which is practically not possible occurring in the existing architecture. To overcome these difficulties different architectures are proposed in this paper. In the first architecture the HA and GGSN is connected to the border router instead of tightly coupling the HA to the GGSN, and the second architecture is HA can be collocated with one of the GGSN in UMTS network and in the third architecture, GGSN is the default router of the mobile nodes (MN) under its coverage area, the foreign agent (FA) is best collocated with the GGSN. Based on the observation of proposed architectures, performance metrics on packet overhead and attempt towards dynamic home agent assignment has been proposed and compared.

1. INTRODUCTION

Next-generation mobile/wireless all-IP networks are expected to provide a substantially wider and enhanced range of services, including global convergence, interoperability, and mobility. To support global roaming, next-generation networks will require the integration and interoperation of mobility management processes under a worldwide wireless communications infrastructure [1].

A cellular data network can provide relatively low-speed (up to 100 kb/s per user) data service over a large coverage area. On the other hand, WLAN provides high-speed data service (up to 11 Mb/s with 802.11b and 54 Mb/s with 802.11a) over a geographically small area [2]. The interworking between WLANs and cellular networks is expected to break new ground for sophisticated business models. While 3G

systems offer large coverage and a rich network infrastructure WLANs have the potential for high data rates which allows fast Web surfing and high-quality video transmission and gaming applications. An integrated network combines the strengths of each, resulting in a wide-area system capable of providing users with ubiquitous data service ranging from low to high speed in strategic locations[3]. WLANs are available in a wide range of devices and are now being viewed as the means of a ubiquitous broadband access platform. 802.11b can provide link speeds of 11 Mb/s and application speeds of 5 Mb/s, and newer standards such as 802.11a/g provide even higher speeds, which is ideal for Internet- based data access.

Public cellular networks have evolved from the first-generation analog cell phones to 2G digital cell phone systems and 2.5G packet-based low-bandwidth cell phone systems to high-bandwidth all-IP wireless 3G networks; presently specifications are being developed for 4G networks. Global System for Mobile Communications is the most popular 2G standard; general packet radio service is its 2.5G and Universal Mobile Telecommunications System its 3G standard. UMTS can provide a maximum of 2 Mb/s or higher data speeds [4]. 3G networks are designed to have wide area coverage for public access to their services; thus, they can be accessed from public areas, businesses, and hotspots. Multimedia messaging (MMS) and IP multimedia subsystem (IMS) are major services to be provided by UMTS. With IMS, users will be able to join teleconferences and receive various location-based services such as guided tours. However, it will take quite a few years until IMS is fully available. [5].

Mobile IP is the standard protocol defined for terminal mobility in the Internet; therefore, Mobile IP is proposed as the basic mechanism to provide service continuity. Mobile IP is the key protocol to enable mobile computing and networking, which brings together two of the world's most powerful technologies, the Internet and mobile communication. In Mobile IP, two IP addresses are provided for each computer: home IP address which is fixed and care-of IP address which is changing as the computer moves. When the mobile moves to a new location, it must send its new address to an agent at home so that the agent can tunnel all communications to its new address timely. The article limits its scope to Mobile IPv4, Mobile IP for IP version 4 [6]. The Internet Protocol version 4 (IPv4) is a fundamental network layer protocol that contains addressing information and some control information that enables data packets to be routed. Mobile IPv4 can provide transparency

to the upper layers while providing seamless mobility using the care-of-addresses. It is noted that Mobile IP provides service continuity, and seamless service continuity can be provided using standardized extensions of the base protocol such as fast handover. Mobile IP requires the deployment of home agents and a protocol between the mobile nodes, home agent, and corresponding nodes. The home agent placement and home address assignment issues are addressed for supporting Mobile IP for heterogeneous roaming. The main objectives of this paper are to integrate WLAN with cellular network using different architecture and to analyze the performance of the proposed architecture.

This paper is organized as follows. The interworking between WLAN and Cellular networks scenarios is presented in Section II. The dynamic home agent assignment is described in Section III. Simulated results are presented in Section IV. Conclusions are given in Section V.

2. INTERWORKED UMTS/WLAN CELLULAR NETWORK

There are two different ways to design an integrated UMTS/WLAN network architecture, defined as tight coupling and loose coupling interworking. Figure 1 shows the architecture for UMTS/WLAN integration. In a tight coupling interworking architecture, a WLAN is connected to an UMTS core network in the same manner as other UMTS radio access networks [7]. The WLAN gateway implements all the UMTS protocols required in the UMTS radio access network. In this approach, UMTS and WLAN would use the same authentication, mobility, and billing infrastructures. The main advantage of this solution is that the mechanisms for mobility, QoS, and security in the UMTS core network can be reused directly over the WLAN [8]. However, tightly coupled solutions will be highly specific to the UMTS technology and require extensive access interface standardization of WLANs beyond the existing standards. Moreover, the configuration and design of UMTS network elements, such as the serving SGSN and GGSN, have to be modified to sustain the increased traffic from WLANs. Tight coupling indeed provides firm coupling between WLAN and GPRS, and its main advantage is enhanced mobility across the two domains, which is entirely based on GPRS mobility management protocols.

More important, tight coupling cannot support legacy WLAN terminals, which do not implement the GPRS protocols. These are some of the reasons that account for the current trend toward loose coupling [9, 10].

On the other hand, the loose interworking approach does not necessitate that the WLAN conform to the complicated 3G access/core network interfaces. Handover from WLANs to 3G and vice versa shall be supported. Some of the WLAN supported user services may not be supportable in 3G networks and/or may not be robust enough for the handover requirements. Services that will suffer from the latter are typically time stringent, as for the former these may be services/applications that require an amount of capacity that is not supported. Further, the WLAN gateway does not have any direct connection to UMTS network elements. WLAN traffic would not go through the UMTS core network [11]. In this approach, UMTS and WLAN can use different mechanisms and protocols to handle authentication, mobility, and billing. Nevertheless, they can share the same

subscriber database for functions such as security, billing, and customer management as peer IP domains. This scheme allows the independent deployment and traffic engineering of UMTS and WLAN. Network operators and service providers can operate these two networks separately through roaming agreements. Loose coupling offers several advantages over tight coupling, such as independent deployment and traffic engineering of UMTS and WLANs.

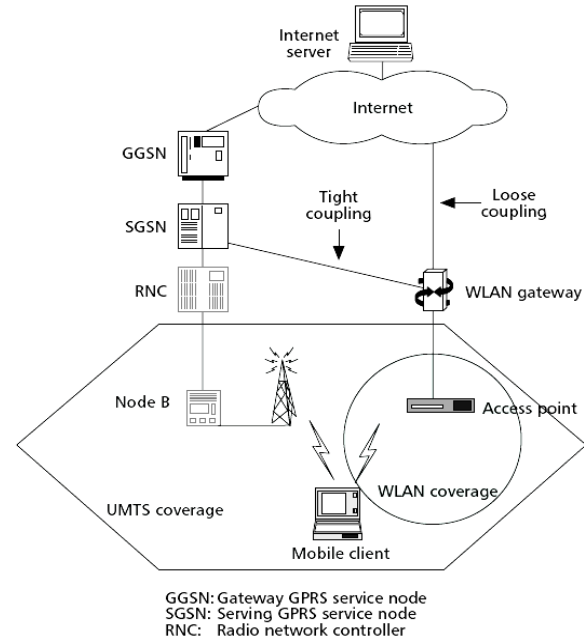


Figure 1. Integrated UMTS/WLAN systems

3. DYNAMIC HOME AGENT ASSIGNMENT

When a mobile terminal (MT) moves from UMTS to WLAN, it performs mobile IP (MIP) registration with home agent (HA). Subsequently, HA needs to perform location update signaling with UMTS network to make the MT reachable from UMTS. If HA is deployed at gateway GPRS support node (GGSN), all incoming packets from the Internet to an MT are routed via GGSN and average packet-delay increases when the MT is in loosely-coupled WLAN. MIP registration is also affected by the traffics between the Internet and UMTS. To avoid this problem, HA can be deployed in UMTS network, but handoff delay from WLAN to UMTS will be more because an MT cannot send MIP-registration request to HA before the establishment of PDP context in UMTS network [12].

There are several requirements for HA placement. For users of UMTS, the HA should be placed in a UMTS network. However, UMTS did not incorporate Mobile IP into its architecture, so any new entities to be added must have minimal impact on overall UMTS operations. Mobile IP requires the deployment of the home agents and a protocol between the mobile nodes, home agent, and the corresponding nodes. In WLANs IP mobility can only be handled with Mobile IP. For seamless communication of MNs roaming between the two networks, Mobile IP needs to be supported in both GPRS/UMTS and WLAN networks. When an HA is placed in a UMTS network for mobiles that roam in WLANs, traffic from CNs is routed to the UMTS network. Assuming the CN will send on average at the

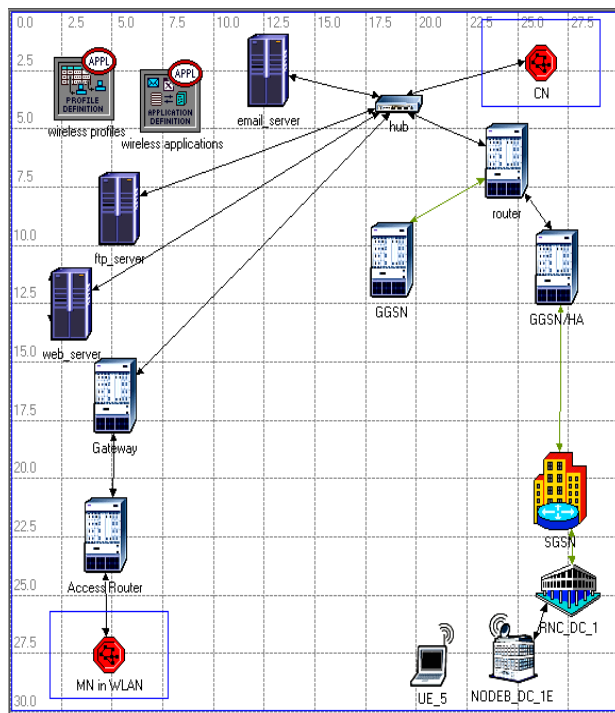


Figure 5. Architecture 2

3.4 Architecture 3

As shown in Figure 6, architecture 3 is a slight modification of proposed architecture 1 with the addition of an FA. Since the GGSN is the default router of the MNs under its coverage area, the FA is best collocated with the GGSN. In this architecture the MN, when roaming in UMTS, needs to select a different GGSN and use it as an FA in getting a CoA (the address associated with the PDP context), and register this address with it's HA

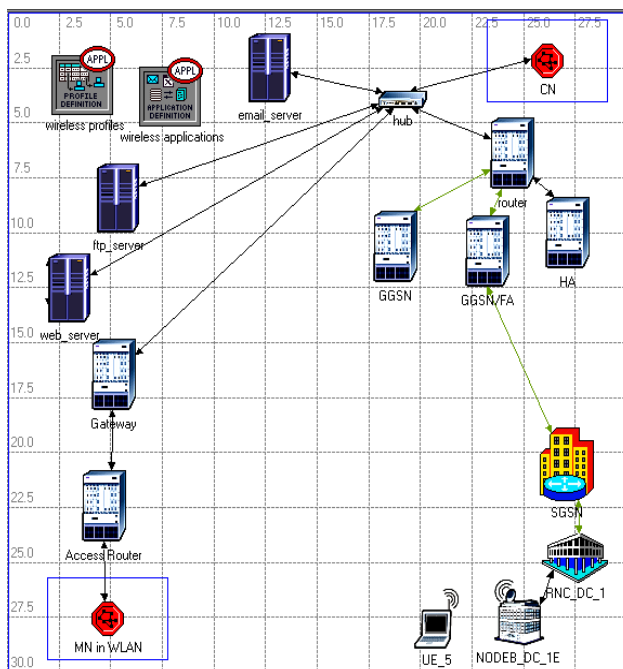


Figure 6. Architecture 3

4. SIMULATION RESULTS

The main objective is to integrate WLAN with cellular networks using different architecture by providing network address/port translation NAT/NAPT traversal. In hotspots, the MN uses WLAN access when the signal strength degrades, and outside of hotspots it uses GPRS/UMTS. The presentation is evaluated and the performance analysis such as latency and packet overhead of these architectures are simulated using optimum network performance (OPNET) and analyzed. The placement of HA in the architecture and routing it in different position provides a difference in their performance. In UMTS, Constant bit rate (CBR), Variable bit rate (VBR), Available bit rate (ABR), Unspecified bit rate (UBR) are used for queue configuration.

The OPNET attributes used for integration of WLAN with cellular network using different architectures are shown in Table 1. All the architectures use the same set of OPNET attributes. The divergence made is, HA placed and routed through different position in the architecture. The graph has been interrupted by taking time in minutes along x axis and throughput in kbps for UMTS and Mbps for WLAN along the y axis.

PARAMETER	VALUE
IP Packet Discard Ratio	0.4%
IP Packet Latency (sec)	0.001
UMTS RLC Processing Time (sec)	0.014.
UTRAN maximum block size (kbps)	64
UMTS GGSN Queue configuration	All categories
WLAN Buffer size (Bits)	64000
Background Traffic start delay (sec)	140
Call Generation Rate	4
UMTS Mobility distance threshold (m)	4
Traffic scaling factor	1
Traffic scaling mode	Background traffic
Tracer packet per interval	2

Table I. OPNET attributes for integrating WLAN and Cellular Networks

4.1 Performance of Existing Architecture

In existing architecture, an HA is placed between the border router and a specific GGSN. The Figure 7 depicts maximum traffic sent through the WLAN is approximately 1 Mbps and the traffic received is nearly 1.75 Mbps which is a converged network of UMTS and WLAN. This slow access is due to the traffic which has to pass through HA in between the border router and a specific GGSN. In UMTS network, the Figure 8 infers that 12 kbps is the transmit load and the received load is 9 kbps. Advantages of architecture this are its simplicity, intrinsic Mobile IP support, and minimal change to UMTS architecture.

A disadvantage of this architecture is that an HA must be able to perform very high-speed routing, as fast as a GGSN. Advantages of existing architecture are its simplicity, intrinsic Mobile IP support, and minimal change to UMTS architecture.

4.2 Performance of Architecture 1

The HA and GGSN can be connected to the border router instead of tightly coupling the HA to the GGSN. An HA in this architecture now can serve all GGSNs in the domain. The Figure 9 explains the maximum traffic sent through the WLAN is approximately 1 Mbps and the traffic received is nearly 2.54 Mbps. This fast access is due to the HA and GGSN connected to the border router and a specific GGSN. In UMTS network, the Figure shown in 10 infer that 42 kbps is the transmit load and the received load is 40 kbps. The advantages of this architecture are its simplicity and scalability. Only one new entity is added to the UMTS network, and the solution is scalable because the HA can be scaled as the number of Mobile IP users increase. Compared with existing architecture, an HA does not need to route all GGSN traffic, which is another advantage for this architecture.

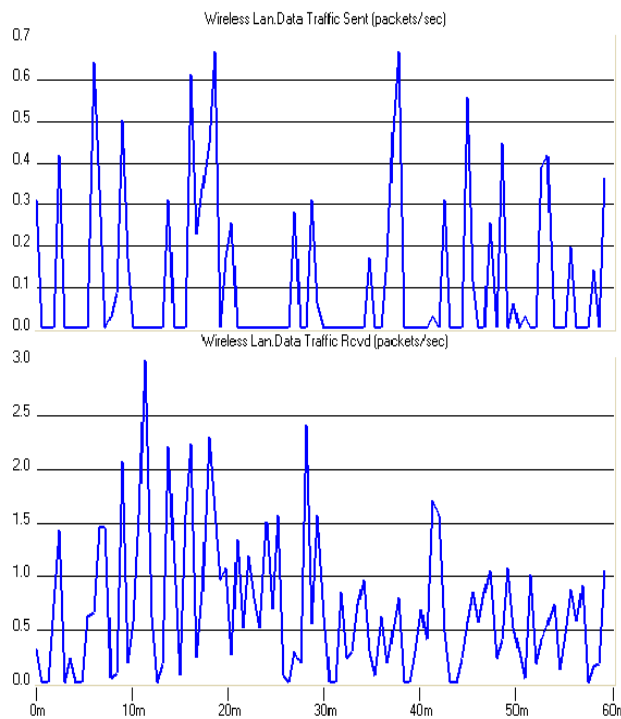


Figure 7. Performance of WLAN in existing architecture

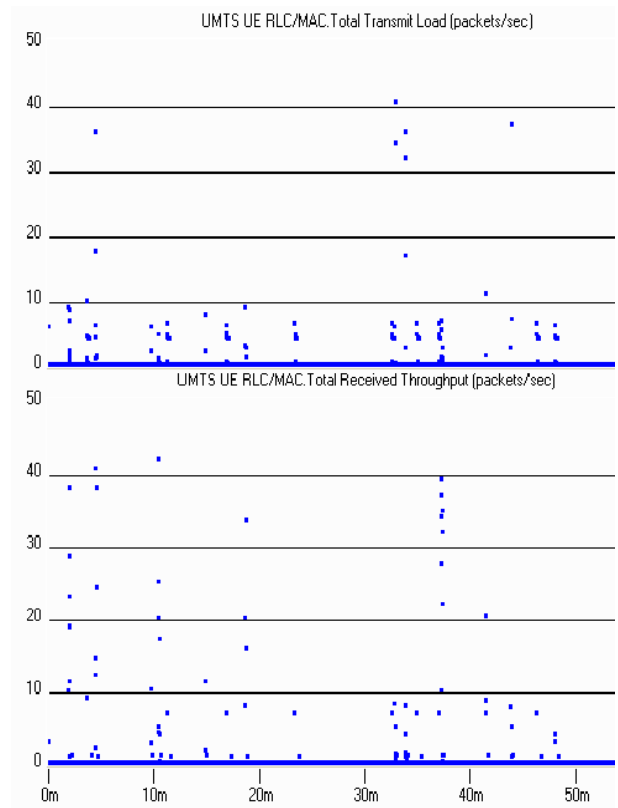


Figure 8. Performance of UMTS in existing architecture

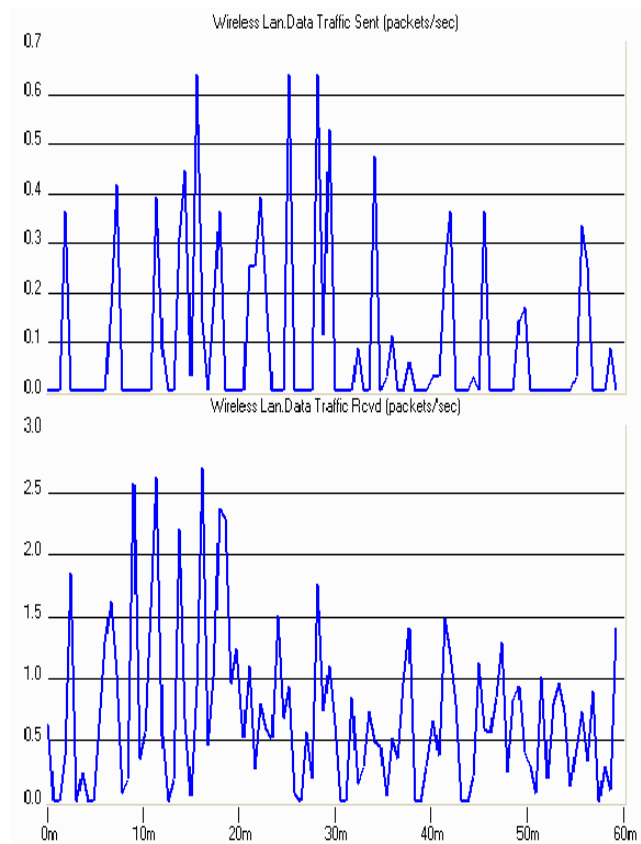


Figure 9. Performance of WLAN in architecture1

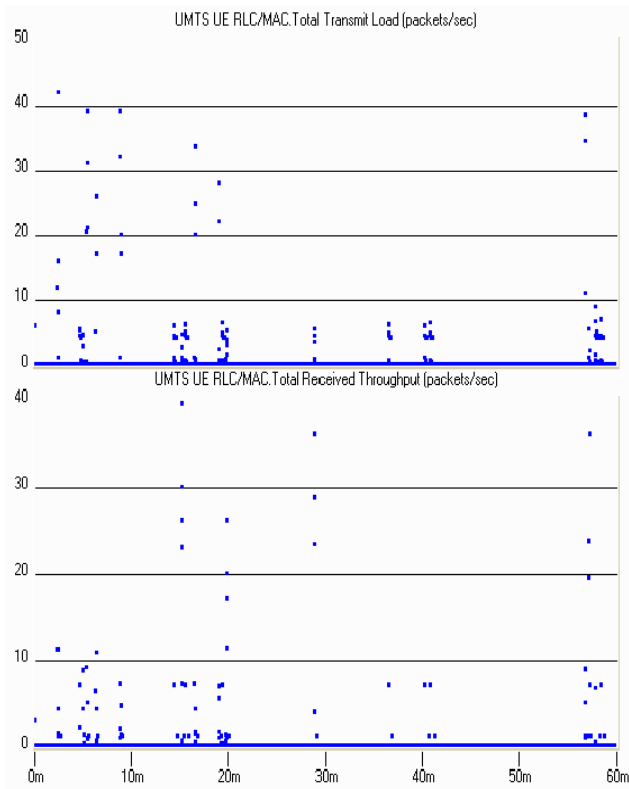


Figure 10. Performance of UMTS in architecture 1

4.3 Performance of Architecture 2

This architecture is a slight modification of existing architecture. The HA is collocated with one of the GGSNs in cellular network. The Figure 11 depicts maximum traffic sent through the WLAN is approximately 1 Mbps and the traffic received is nearly 2.84 Mbps. This fast access is due to the HA is collocated with one of the GGSNs.

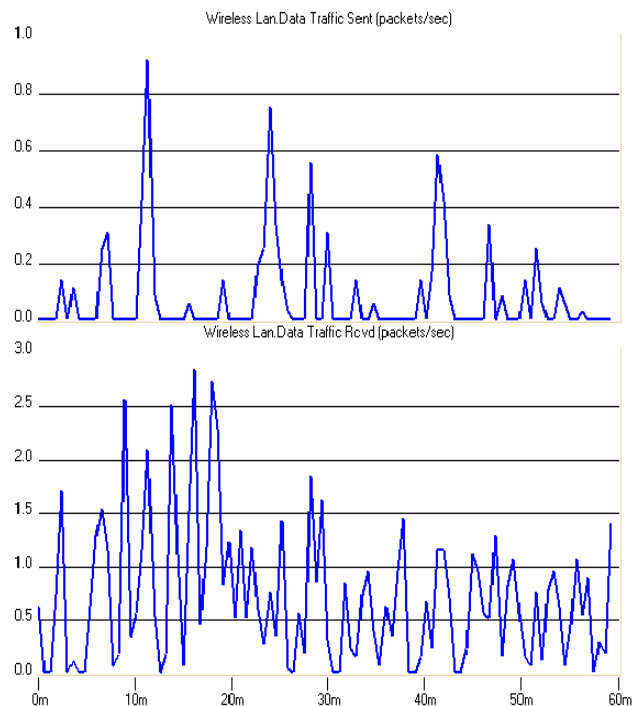


Figure 11. Performance of WLAN in architecture 2

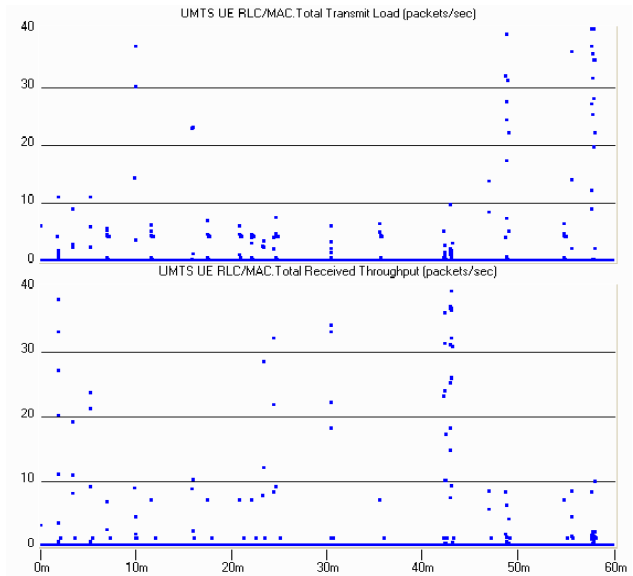


Figure 12. Performance of UMTS in architecture 2

In UMTS network, Figure 12 infers that 41 kbps is the transmit load and the received load is same. An advantage of an HA being collocated with a GGSN is that in this case HA does not need to perform proxy address resolution protocol (ARP) interactions for the MNs. In UMTS network, MNs are in their home network and therefore do not need any Mobile IP services and this add another advantage.

The disadvantages of architecture 2 are the load of HA operations that are added to the GGSN and the need to reserve HoAs assigned to MNs when they roam into WLANs. These disadvantages do not exist in existing architecture. Among the proposed architectures this architecture founds to be better because of its better result in WLAN which is a converged series and its optimal routing in UMTS network.

4.4 Performance of Architecture 3

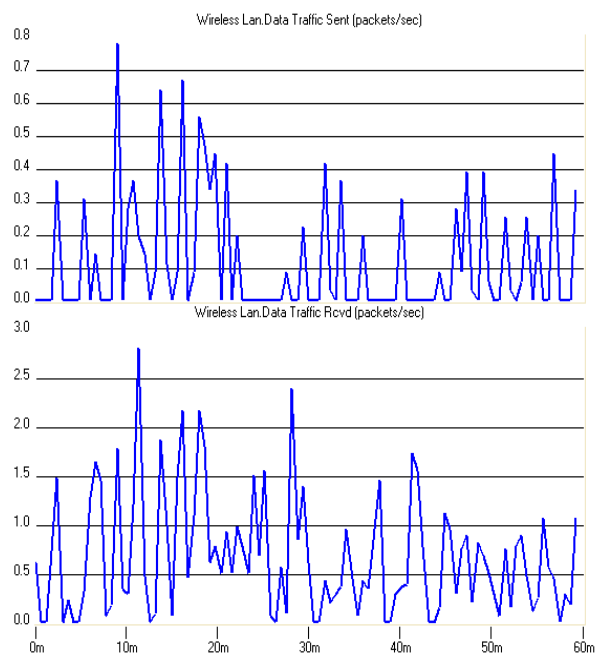


Figure 13. Performance of WLAN in architecture 3

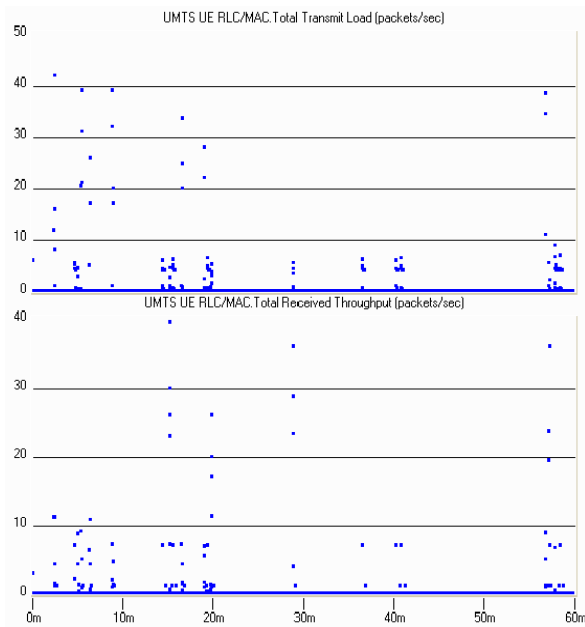


Figure 14. Performance of UMTS in architecture 3

Architecture 3 is a slight modification of architecture 1 with addition of an FA. In WLAN as shown in Figure 13 the traffic sent is 1 Mbps and received about 2.75 Mbps where as in UMTS network, Figure 14 infers that 41 kbps is the transmit load and received load is 40 kbps. Since GGSN is default router of MNs under its coverage area, FA is best collocated with GGSN. In architecture 3 the MN, when roaming in UMTS, needs to select a different GGSN and use it as an FA in getting a CoA (the address associated with PDP context), and register this address with its HA.

The disadvantage is that operation of Mobile IP is a partial replacement of UMTS' GTP; GTP and Mobile IP together introduce redundant mobility handling operations such as encapsulation/decapsulation in data path.

When MN enters in WLAN, it enhances signal through WLAN by loose coupling architecture. Table 3 depicts performance of WLAN\UMTS in converged series whereas table 4 infers comparison of different architectures. Various architectures used in practice have its own advantage. HA placement plays an inferior role in delay, but during data transfer, closer the HA is placed, higher the bandwidth. The architecture 2 shows superlative result in WLAN and optimal routing in UMTS.

ARCHITECTURE	WLAN TRAFFIC SENT(Mbps)		UMTS LOAD(kbps)		INFERENCE
	TRANSMITTED	RECEIVED	TRANSMITTED	RECEIVED	
Existing Architecture	1	1.75	12	9	Average result in WLAN and poor outcome in UMTS
Architecture 1	1	2.54	42	40	Fine result in WLAN and enhanced routing in UMTS
Architecture 2	1	2.84	41	41	Superlative result in WLAN and optimal routing in UMTS
Architecture 3	1	2.75	41	40	Better result in WLAN and enhanced routing in UMTS

Table II. Performance of WLAN\UMTS in converged series

ARCHITECTURE	VARIATION IN ARCHITECTURE	ADVANTAGE	DRAWBACK
Existing Architecture	HA placed between the border router GGSN	Simplicity, intrinsic Mobile IP support, minimal change to UMTS.	HA able to perform very high-speed routing, as fast as GGSN.
Architecture 1	HA and GGSN connected to border router	Simplicity and scalability.	HA does not route all GGSN traffic.
Architecture 2	HA collocated with one of the GGSN	HA does not need to perform proxy address resolution protocol interactions for MN.	HA operations are added to GGSN and need to reserve HoA assigned to MNs when they roam into WLANs.
Architecture 3	FA is collocated with GGSN along HA	UMTS selects GGSN and uses it as FA in getting a CoA and register this address with its HA.	Mobile IP performs partial replacement of UMTS' and introduces redundant mobility.

Table III. Comparison of different architectures

5. CONCLUSION

In this paper, performance of dynamic home agent assignment in WLAN with cellular networks using different architecture are simulated using OPNET and results of the architecture are examined. In existing architecture, UMTS has poor outcome and average result in WLAN whereas architecture 2 shows superior results when integrated. This concludes that architecture 2 is best among the proposed architecture. Future research focuses on IP address management technique for different proposed architectures. Technical means of continuity of the accounting session when handover from 3G to WLAN domain or vice versa need to be investigated in order to arrive at solutions for integrated charging. Route optimization is a Mobile IP concept in which CNs can be made to direct their packets to an MN. There are still several challenges like mobility management, Qos, unified billing to be addressed to enable seamless interworking of WLAN and UMTS networks.

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