An OSPF based UMTS/WLAN Radio over Fiber Convergence Network for Enhanced Quality of Service

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Abstract

Wireless community these days debate frequently about convergence (next generation) network, a wireless system that is likely to appear after the successful deployment of the current third-generation (3G) systems. Towards convergence of various wireless networks, the integration of universal mobile telecommunication system (UMTS) and wireless local area network (WLAN) plays a major role. Enhancing quality of service (QoS) in an UMTS/WLAN convergence network is an important issue. This paper proposes radio over fiber (RoF) based UMTS/WLAN convergence network using open shortest path first (OSPF) protocol for enhanced QoS. In this paper, RoF based convergence network is analysed using routing information protocol (RIP), intermediate system-intermediate system (IS-IS) protocol and OSPF protocol, using optimised network engineering tool (OPNET). The simulation results show that the proposed OSPF based convergence network outperforms in QoS compared to existing, RIP and IS-IS based approach.

Keywords:
OSPF, UMTS/WLAN, RoF, Convergence Network, QoS and OPNET.

1. Introduction

Convergence of IEEE 802.11 WLAN and UMTS network has become a trend in wireless services. 3G UMTS provides wide and continuous coverage with low data rates. On the other hand, WLAN provides high data rate with limited coverage. Although, they are heterogeneous wireless access networks, they possess complementary characteristics that can be exploited to the advantage of both UMTS and WLAN network operators and their subscribers. Though WLAN provides higher data rate than UMTS cellular network, it does not provide architecture beyond basic radio access, i.e., universal roaming ability. Thus, the convergence of these two systems can combine their best features to provide ubiquitous access while mediating weakness of both systems. One major challenge in seamless convergence of WLAN with UMTS cellular networks is the design of reliable, robust and efficient architecture. Currently there are two major existing proposals for UMTS/WLAN convergence network architecture, namely tight coupling and loose coupling. Although the above two schemes are used widely, they have their own disadvantages. Cho, D *et al* (2003) has proposed a hybrid coupling technique to overcome their disadvantages.

Gan Liu et al (2008) proposed a converging architecture using radio over fiber (RoF) technique in order to enhance QoS. Compared with the existing coupling schemes, RoF convergence network can distribute the signaling and data load on both UMTS core network and core internet and have less handoff latency in vertical handoff process. To enhance the QoS of RoF convergence network, internet protocol version 6 (IPv6) based routing protocol called RIP, IS-IS and OSPF can be used, among which OSPF outperforms interms of QoS. Wikipedia states, OSPF is an adaptive routing protocol for IP networks. It uses a link state routing algorithm and falls into the group of interior routing protocols, operating within a single autonomous system.

The rest of the paper is organised as follows: UMTS/WLAN convergence network is described in section 2. In section 3, RIP, IS-IS and OSPF protocols based on IPv6 suite are discussed. In section 4, simulation parameters and simulation scenarios created in OPNET version 14.5, for various coupling schemes are discussed. In section 5, the simulation results are provided to compare the performance of convergence network based on OSPF with that of existing techniques and other two protocols. Section 6 concludes this paper.

2. UMTS/WLAN Convergence Network

Shankar R et al (2010) mentioned, the standard developing bodies have attempted to define standards for the interoperation of the two systems and several researchers are seeking the best methods to interwork the two systems. In this section, the existing coupling schemes for the UMTS/WLAN convergence are discussed.

2.1 Loose and Tight Coupling

Loose coupling is generally defined as the utilisation of WLAN as a packet based access network complementary to UMTS networks. A loosely-coupled architecture allows a WLAN to bypass the 3G core network and interface directly to the core IP network via a WLAN gateway. This approach completely separates the data paths in the WLAN and UMTS networks. Therefore the WLAN data traffic is never injected into the UMTS core network. It allows for independent deployment of WLAN and UMTS networks and roaming agreement can be established between the operators of the two networks. Therefore minimal modifications to UMTS network are required. WLAN security, mobility and QoS issues are addressed using internet engineering task force (IETF) schemes.

In tight coupling, WLAN is directly connected to UMTS core network. Consequently, all WLAN traffic is injected into the UMTS core data network. As a result, serving general packet radio service (GPRS) support node [SGSN] and gateway GPRS support node (GGSN) has to be modified to handle the higher bit rates supported in the WLAN network. The major advantage is that the IP addresses at the mobile station can be maintained and the QoS can be guaranteed. This approach is only feasible when both WLAN and UMTS network belong to the same operator. The complexity and high cost of reconfiguring the 3G core networks and WLAN gateways are major factors that make the tightly coupled approach less competitive.

2.2 Hybrid Coupling and RoF based Convergence Architecture

Hybrid coupling is the combination of both loose coupling and tight coupling. Inheriting loose and tight coupling techniques, hybrid coupling utilises standard air interface to set up direct wireless communication between UMTS cellular network and WLAN. A hybrid coupling scheme differentiates traffic paths according to the type of the traffic. In loose coupled network, real time traffic could not have appropriate delay and jitter when forwarded through WLAN and internet. Thus, the traffic experiences large packet loss or whole packets are even blocked. But when connecting WLAN to UMTS based on hybrid coupling scheme, it is possible to support quality of service of real time traffic. When tight coupling scheme is applied, packet loss may decrease, but if bulky data traffic like file transfer protocol (FTP) flows into the cellular core network from WLAN, packet loss rate in core network would abruptly increase. But hybrid coupling scheme can prevent core network nodes from traffic overflow by means of detouring non-real time traffic of WLAN.

The RoF convergence network proposed by Gan Liu et al (2008) adopts RoF technique that directly transmits radio signal on optical fiber. In this architecture, the WLAN server and access point (AP) are connected with fiber distributed data interface (FDDI) cable. The AP transmits the radio signal to WLAN server by RoF technique. Thus mobile node builds up a connection with WLAN. Liu C et al (2005) considered both WLAN and UMTS networks to be IPv6 based networks and each node in the network have unique IP address.

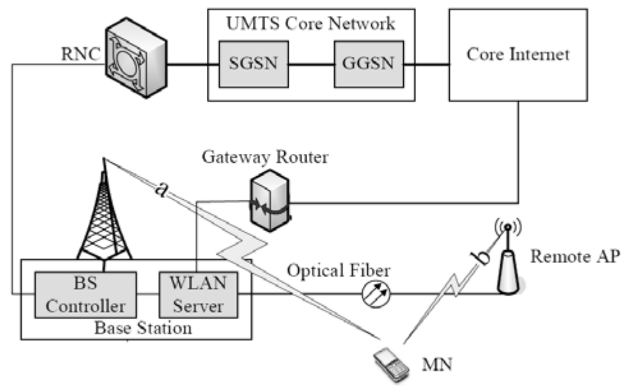

Fig. 1 RoF based convergence architecture

When a mobile node (MN) is in UMTS cellular network as in figure 1, it directly connects with the base station (BS) by wireless link "a". While the MN is in WLAN, it connects with remote AP by wireless link "b". The remote AP transmits 2.4GHz radio signal to WLAN server by RoF technique and builds up a connection with WLAN.

RoF convergence architecture has following advantages: The BS controller of UMTS cellular network and server of WLAN are located nearer, as a result interchanging traffic between them will not burden core networks. MN is always connected with BS, the process of vertical handoff becomes simpler and communication is not disrupted during vertical handoff. The bandwidth of optical fiber is much broader than radio signal; consequently RoF signals only occupy a little bandwidth of optical fiber.

3. RIP, IS-IS and OSPF Protocols

IPv6 is a family of protocols that will augment or replace the existing IPv4 family of protocols. The interior routing protocols for IPv6 include next generation routing information protocol (RIPng), intermediate system to intermediate system (IS-IS) and OSPFv3 protocol. In a convergence network, the network will be organised as a collection of autonomous systems (AS), each of which will, in general, be administered by a single entity. Each AS will have its own routing technology, which may differ among AS's. The routing protocol used within an AS is referred to as an interior gateway protocol (IGP). A separate protocol, called an exterior gateway protocol (EGP), is used to transfer routing information among the AS's. RIPng was designed to work as an IGP in moderate-size AS's as mentioned by Malkin, G et al (1997). It is not intended for use in more complex environments. It is a distance vector protocol, which employs the hop count as a routing metric. RIPng is intended to allow routers to exchange information for computing routes through an IPv6-based network. Any router that uses RIPng is assumed to have interfaces to one or more networks. The protocol relies on access to certain information about each of these networks, the most important of which is its metric. In addition to the metric, each network will have an IPv6 destination address prefix and prefix length associated with it. Each router that implements RIPng is assumed to have a routing table. This table has one entry for every destination that is reachable throughout the system. RIP is not the preferred choice for routing as its time to converge and scalability are poor and a hop limit severely limits the size of network it can be used in. However, it is easy to configure, because RIP does not require any parameters on a router unlike other protocols.

IS-IS is an internal routing protocol designed by the international standard organization (ISO). It is a link state protocol, contains a "hello" protocol to discover neighboring nodes, and uses a "flooding" protocol to propagate link information. IS-IS uses a sequence number for messages. When the counter reaches the "ceiling" an IS-IS router has no option but to fake a failure and trigger a purge of all old information. However, this is not a problem since the sequence numbers used are 32 bits long, giving a very large sequence number space before a ceiling is reached. Originally IS-IS was developed purely for use on open system interconnection (OSI) networks, but a version has been developed that can handle both OSI and IPv4 networks. IS-IS follows the hierarchical OSI model which dictates fairly rigid constraints on the organisation and connectivity of sub networks. On OSI networks this rigidity is compensated by automatic address assignment to form "areas", but when used for IP it retains the rigidity without offering any real advantages. Petri Wessman (2000) mentions that it is possible that IS-IS implementations for IPv6 will utilise the auto configuration options of IPv6 to bring it closer to the OSI model of operation.

OSPFv3 protocol is a link state routing protocol based on OSPFv2 with a number of modifications. OSPFv3 exchanges IPv6 routing information, while OSPFv2 exchanges IPv4 routing information. All nodes maintain a complete "map" of the network, and perform local computation of best routes based on this internal map. This prevents packet looping, since the internal map is always kept at a coherent state. Changes in the network topology are propagated to all nodes quickly by a "flooding" protocol. OSPF includes three different protocols. The "hello" protocol checks that links are operational and is also used to negotiate a "designated router" and a backup. The "exchange" protocol is used to synchronize databases between two nodes, with one node acting as "master" and the other as "slave". The "flooding" protocol is used to propagate changes in link state to other nodes in the network. When a network of OSPF nodes is brought up, each node must discover its peers and build up its database of the network topology. To simplify this step and to limit the number of exchanges needed, OSPF nodes "elect" one of the nodes to act as a designated router, and one additional router to act as backup for the designated node in case it fails. All nodes synchronize themselves with the designated router, speeding up the start process. The designated router also acts as coordinator by sending "flooding" messages. To avoid corrupted routing information, each OSPF packet contains a sequence number which can be used to discard old messages. OSPF also includes security provisions to protect against intruders.

4. OPNET Scenarios

In this section, existing UMTS/WLAN convergence network architectures as discussed by Marwan Abu Amar *et al* (2007), RIP, IS-IS and the proposed OSPF based RoF convergence network simulated in OPNET is discussed. The simulation parameters used for simulating the scenarios is listed in table 1.

The OPNET scenario that follows loose coupling architecture discussed by Ahmavaara, K et al (2003) is shown in figure 2 , Here WLAN router is connected to the IP cloud, which separates the data paths in the WLAN and UMTS networks. Therefore the WLAN data traffic is never injected into the UMTS core network. In tight coupling architecture shown in figure 3, WLAN router is connected to the SGSN, thus all the WLAN traffic are injected into the UMTS core data network.

Table 1: Simulation parameters

Parameter	***Value***
WLAN transmit power(W)	0.005
IP packet latency(s)	0.001

Packet discard ratio	0.5%
UMTS radio link control (RLC) processing time (s)	0.014
UMTS terrestrial radio access network (UTRAN) maximum block size (kbps)	64
WLAN buffer size (bits)	64000
Call generation rate	4
UMTS mobility distance threshold (m)	4
Traffic scaling factor	1

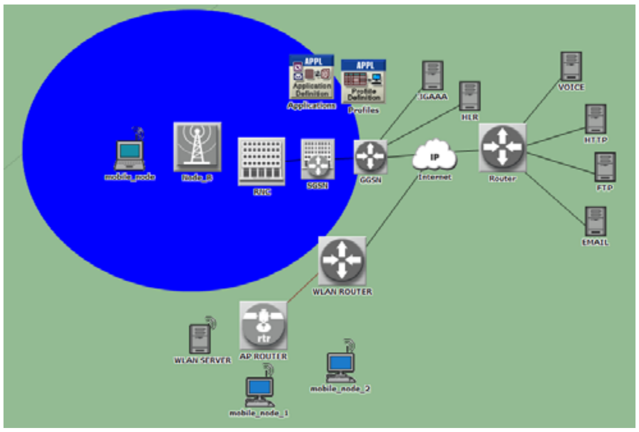

Fig. 2 Loose coupling architecture

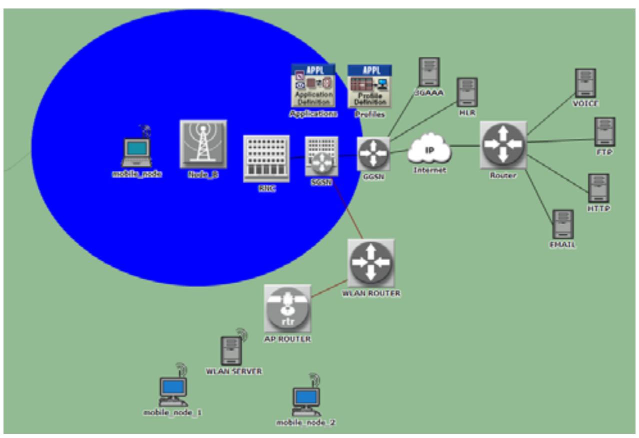

Fig. 3 Tight coupling architecture

Hybrid coupling is the combination of loose coupling and tight coupling and so the WLAN router is connected wih both IP cloud and SGSN, as in figure 4. Here, AP router and WLAN router are connected with ethernet cable.

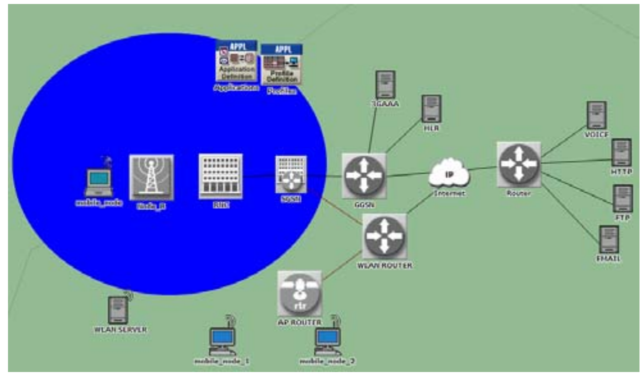

Fig. 4 Hybrid coupling architecture

RoF convergence architecture shown in figure 5, created in OPNET is similar to that of the hybrid coupling in which except the AP router and WLAN router are connected with FDDI cable instead of Ethernet cable. RoF convergence architecture follows IPv6 addressing.

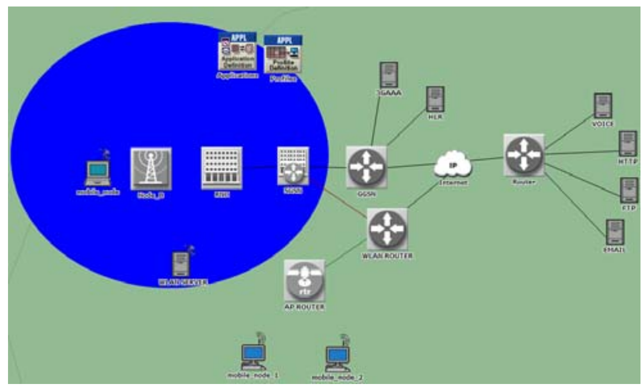

Fig. 5 RoF convergence architecture

RoF convergence architecture using RIP and IS-IS are shown in figures 6 and 7 respectively. These are the OPNET snapshots in which the routing protocols of IPv6 suite has been enabled in the router interfaces.

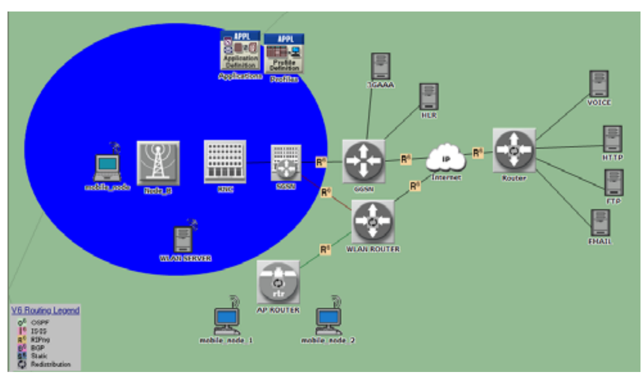

Fig. 6 RoF architecture using RIP

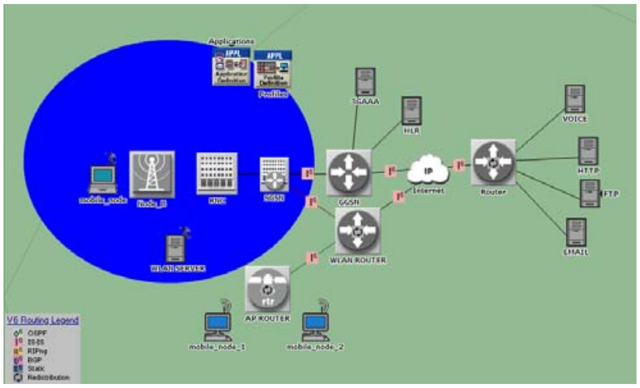

Figure 7 RoF architecture using IS-IS

In the RoF OPNET architecture, OSPF protocol is enabled along with IPv6 addresses assigned, as shown in figure 8.

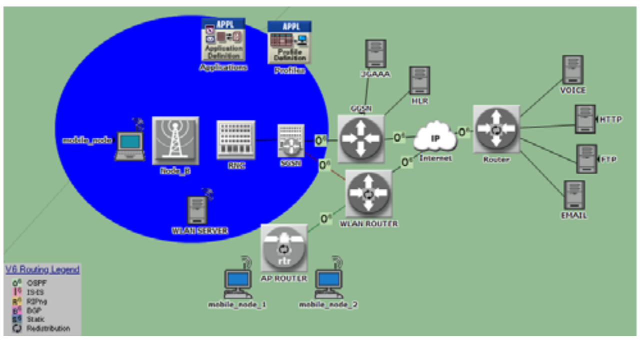

Figure 8 RoF architecture using OSPF

5. Simulation Results

In this section, the simulation results for convergence network scenarios of loose coupling, tight coupling, hybrid coupling, RoF convergence architecture, RoF convergence architecture using RIP, IS-IS and OSPF simulated in OPNET is presented and compared for their performance in terms of QoS.

Figure 9 shows the performance of WLAN system in terms of network delay. It is vivid from the results that when OSPF is used in RoF convergence architecture, the delay in the network is very less compared to other schemes. More over it is observed that, hybrid coupling architecture discussed by kin, k. et al (2005) has highest delay due to network complexity. Loose coupling has 20% less delay due to independent deployment and traffic engineering of IEEE 802.11 and UMTS networks as mentioned by Feder, P. et al than hybrid coupling. Tight coupling has 2% less delay inspite of heavy burden imposed to the core 3G network and core internet as mentioned by Ching Wen Cheng et al (2007) than loose coupling and RoF has 6% less delay due to the advantages of fiber optic link between WLAN and AP router compared with tight coupling technique. RoF using IS-IS has 11% less delay due to router's exchange of topology information with neighbours than RoF convergence architecture, RoF using RIP has 2% less delay, because of its simplicity and less computational overheads as mentioned in routing information protocol (1999), than RoF/IS-IS. RoF using OSPF has 3% lesser delay because of complete knowledge of routers about the topology as mentioned in Meta networks (1999), compared with RoF/RIP.

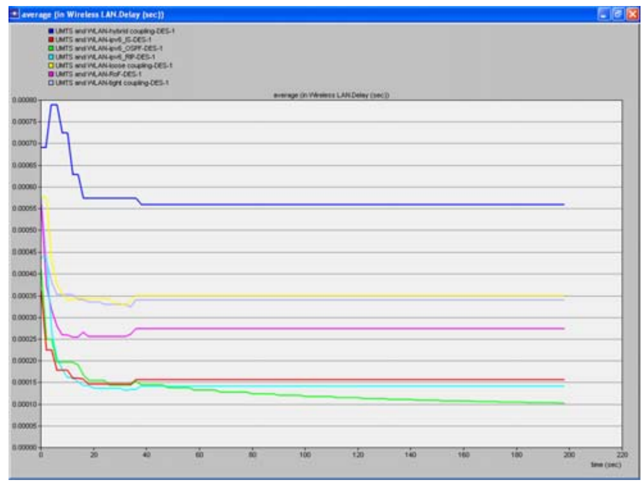

Figure 9 WLAN delay

The figure 10 shows throughput performance of the system. RoF using OSPF has higher throughput than the other schemes.

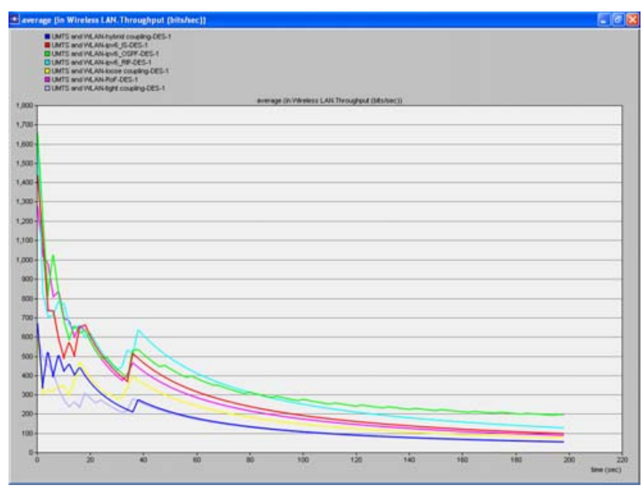

Figure 10 WLAN throughput

From the results, it is observed that the tight coupling has very less throughput due to heavy burden at the 3G core, loose coupling has 1% higher throughput due to less over burdening of 3G core than tight coupling. Hybrid coupling when followed for converging UMTS/WLAN has 23%

higher throughput because of its adaptivity, than loose coupling scheme. Compared to hybrid coupling, RoF convergence network has 32% higher throughput due to the advantages of fiber optic link between WLAN and AP router, when RoF uses IS-IS the throughput increases further by 9%. RoF/RIP has 11% higher throughput than RoF/IS-IS. Further from the result it is inferred that there is an increase in throughput by 4% for RoF that follows OSPF, compared to RoF convergence architecture that follows RIP.

Figure 11 shows the result for WLAN load in the network. RoF convergence network following OSPF handles large network load (bits/sec). UMTS/WLAN convergence network that follows hybrid coupling scheme handles less load, RoF using IS-IS handles 20% higher load than hybrid coupled architecture. When RIP is enabled on RoF, load handled is increased by 10% compared to RIP/IS-IS. With tight coupled convergence architecture, RoF and OSPF enabled RoF can handle 10% higher load than RoF/RIP. Loose coupling can handle 5% more load than tight coupling, RoF and OSPF enabled RoF.

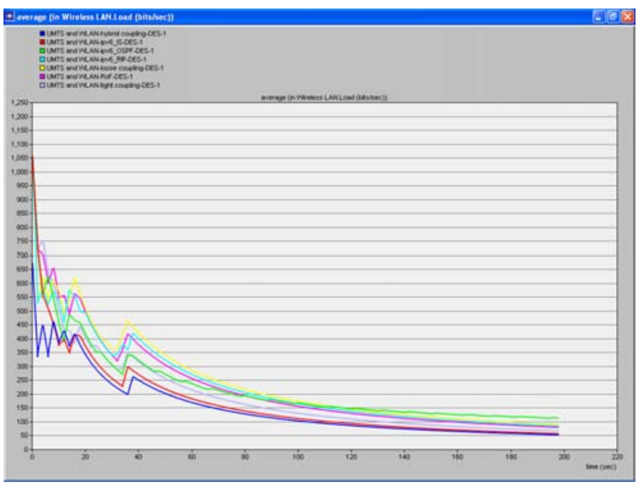

Figure 11 WLAN load

Figures 12 and 13 shows the result for IP traffic received and sent in (packets/sec) respectively. When RoF convergence network follows OSPF, the nodes in the network receive and deliver more packets/sec compared with all the other schemes. From the figures it is inferred that the nodes in the tight coupled UMTS/WLAN convergence network has very less delivery and reception of packets per second, whereas RoF using IS-IS has comparatively higher traffic than tight coupling scheme, further loose coupled, hybrid coupled, RoF and RoF using RIP has higher traffic sent and received compared to RoF using IS-IS. A node in RoF convergence network that follows OSPF has higher traffic sent and received compared to all other schemes.

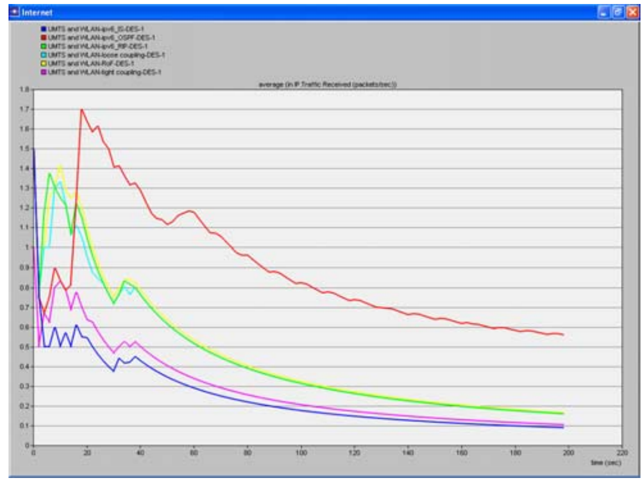

Figure 12 IP traffic received

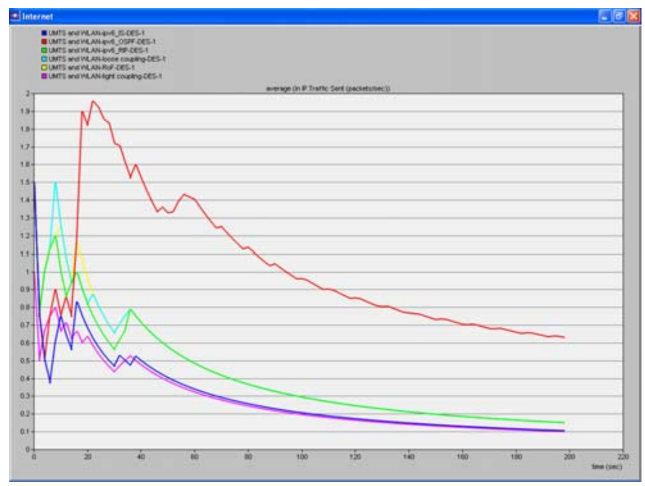

Figure 13 IP traffic sent

6. Conclusion

In this paper, an UMTS/WLAN RoF convergence network based on OSPF is proposed, RoF based convergence network is analysed using RIP, IS-IS and OSPF protocol using OPNET. The performance of proposed convergence network is compared with the existing coupling schemes. Simulation results show that the proposed convergence architecture outperforms UMTS/WLAN convergence network using existing coupling schemes, RoF convergence network using RIP and IS-IS, in terms of QoS.

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