Heterogeneous interface MN support in NS2

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Abstract— Emerging wireless technologies incorporate different access networks. Bluetooth, Wireless Fidelity (Wi-Fi), Universal Mobile Telecommunication System (UMTS) and Worldwide Interoperability for Multiple Access (WiMAX) technologies form heterogeneous network characterized with high resource demand and rapidly changing traffic patterns. Limited co-existence of all mobile users is attributed to poor adaptation of infrastructure and increasing demand of applications/services. More problem of deteriorating service is offered in switching between different access technologies and/or between multiple operators. Subsequently, mobile users experience service disruptions, which make carriage of two or more devices expedient for continuous service to be enjoyed while leaving 'home' network area. Though, some projects have implemented multiple Wi-Fi interfaces, the mobile node only provides for single Wi-Fi or dual WLAN interfaces, which does not allow researchers simulate flexible scenario as users cannot implement switching to other interfaces. To access diverse networks therefore, mobile users needs to be equipped with multi-media enabled wireless device to use real-time application anytime anywhere on diverse network. This paper presents an implementation of multiple channels, multi-interface mobile node in NS2 using Wi-Fi, Bluetooth, UMTS and WiMAX technologies to overcome highlighted limitations. The model provides seamless roaming capability for users across different networks to offer qualitative and continuous service while moving.

Keywords - Heterogeneous interface, Mobile Node, NS2, Quality of Service

1 INTRODUCTION

Heterogeneous network as an integration of different access networks is characterized with high resources demand and rapidly changing traffic patterns [1]. Mobile users here require multiple communication sessions of voice, text or video (multimedia) data, hence hybrid handover process is demanded. Data rate disparity and incompatibility of existing wireless technologies limits free roaming across the different networks. To facilitate connection to different networks, mobile users must be equipped with cognitive wireless devices capable of switching to the best available access network. The objective of this paper is to create heterogeneous multiple channel multi-interfaces MN equipped with Wi-Fi, UMTS, Bluetooth and WiMAX technologies. Incorporating access networks into one multi-radio model offer opportunity to simulate 4G and future generation (FG) devices and scenarios.

Network simulator 2 (NS2) is an open source and widely used simulator used for studying the performance of communication networks [2]. Its characterized flexibility and modular structure, nominated it for studying wireless network functions. By default, NS2 provides support for single interface MN and so specifying multiple interfaces with multiple channels must be provisioned/supported on each MN. NS2 basic architecture enables the use of two languages, providing users with executable commands of TCL simulation script for input parameters and animation or text-based output parameters. To facilitate an application of machine intelligence and adaptive communication technologies for optimized resource usage in wireless networking is the main goal of this research.

An easy to use (Object Tool Command Language) OTCL scripting tool serves as a frontend to configure a network, assembling network objects and scheduling discrete events while C++ as a backend defines the interval mechanism of the simulation objects, handling the data (packets, protocol C++ and OTCL are linked together using a TCLCL interpreter [3].

2 EXISTING PROJECTS

Existing projects implemented in NS2 to provide multiple interface support are characterized with limitations ranging from single interface support to static routing agent. Most of these projects are equipped with manual configuration to implement only Wi-Fi as the only interface provided by default in NS2. Some of these are TENS, HYACINTH, NS-MIRACLE and NS-Multiple Interface (homogeneous interfaces).

The Enhanced Network Simulator (TENS) project implemented for WLAN (IEEE 802.11a) technology was developed at the Indian Institute of Technology, Kanpur. Aimed at improving the ns-2.169a implementation, loop was used to add interface in ns-mobilenode.tcl and model was based on multiplexing of the physical layer [4]. Hyacinth project was implemented for ns-2.169b to emulate IEEE 802.11b physical layer using static configuration. All nodes used within scenario were designed to contain five interfaces each and this static configuration limited the flexibility of the multiple interface capability. Characterized with limitations of static TCL configuration of homogeneous interface, the mobile node only enabled NS2 default routing agents [5]. NS2 multiple interface cross-layer extension projects was implemented on NS 2.29X to accurately model channel and PHY layer functions and the extension enabled interoperability and reusability [6]. NS2 multiple interface support for mobile node implemented on NS2.33 multiplexed physical and link layers of MN and the routing agent modified to use the multiple interface facility. The project was implemented to support multiple interfaces

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by calling the add-interface procedure manually for as many times as the number of interfaces defined. Major limitations of using only Wi-Fi interface and inflexibility of adding heterogeneous interfaces to the many channels were major constraints to design flexibility [7].

By default, NS2 provides support for one propagation model to be used by an interface as shown in fig. 1. Since the basic architecture of mobile node (MN) consist of modules emulating entities link layer, MAC protocol, ARP, interface queue and network interface as contained in real-life protocol stack, all entities used by an interface are connected to share same wireless channel and use one propagation model. With multiple channel homogeneous support provided for each MN, one propagation model is used to simulate the effect of real wireless channel on transmitted signal. After routing agent, the chain of all module entities is multiplexed as many times as the number of channels an interface has at node.

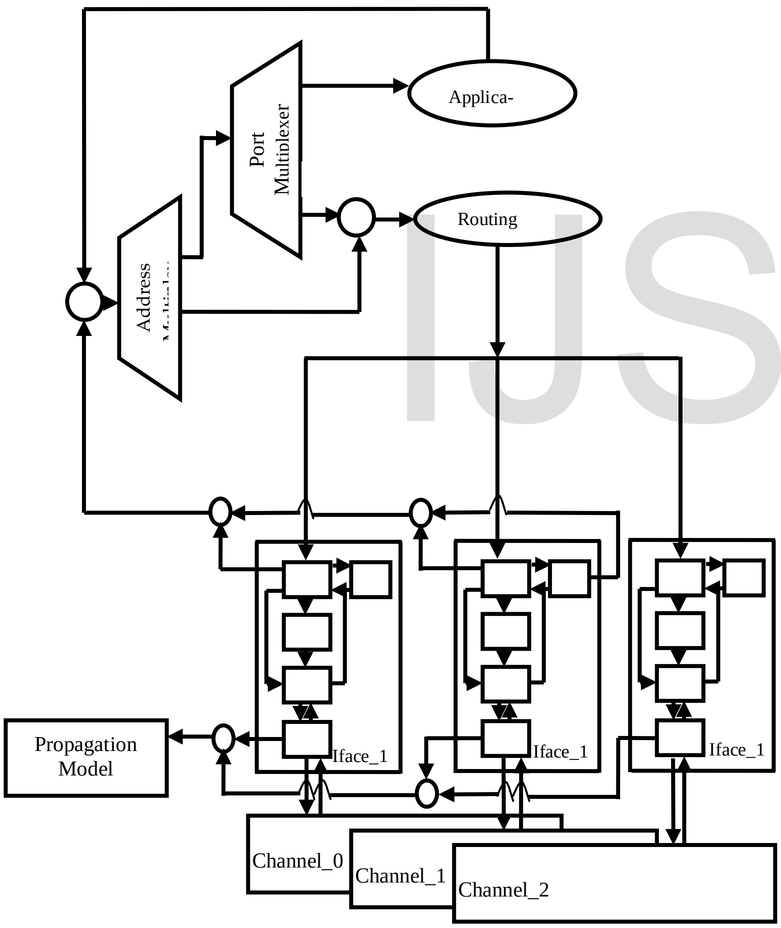

Fig. 1 Multiple channel on homogeneous interface

By default, IEEE 802.11 networks in NS2 is enabled to use more than one channel at a time on the interface Incoming packets received through corresponding channel travel through different entities in ascending order to the link layer. All link layers are connected to same routing agent to select appropriate channel to receive packets while outgoing traffic routes packets to select channel where packets will be transmitted. To add another interface, a loop is created as a procedure to be called as many times the number of interfaces to be supported. This limits design flexibility.

3 ARCHITECTURE OF MULTIPLE HETEROGENEOUS INTERFACE MN

NS2 basic architecture of mobile node (MN) consisting of modules emulating network entities. These entities, link layer, MAC protocol, Address Resolution Protocol (ARP), interface queue and network interface contained within the protocol stack defined for multiple channel heterogeneous interface is shown in fig.2 (appendix). All entities used by selected interface are connected to share same wireless channel using appropriate propagation model. With multiple heterogeneous interface provided for each MN, one propagation model each is used to simulate the real wireless channels available with selected interface while transmitting signals. Routing agent implementation causes the chain of all module entities on each channel to be multiplexed onto the interface entry point into upper layer.

Incoming packets received through corresponding channels travel through network entities in ascending order through Network Interface, MAC and Interface Queue to the link layer. All link layers are connected to same routing agent and multiplexed to the upper layer. Routing agent is dynamically modified to select appropriate channel through which the incoming packets are received. Similarly, outgoing traffic routes packet over the modified routing agent to select which channel of selected interface outgoing packets are transmitted.

MN heterogeneous multiple interface architecture depicted in fig. 2 (see appendix) enables an implementation of several access technologies using reconfiguration techniques shown in fig. 3. The algorithm dynamically offers more robustness in design as need for separate propagation model for the interfaces feature flexibility of design. Therefore, with dynamic reconfiguration, UMTS or IEEE 802.11, 802.15 or 802.16 interfaces use customized propagation model for its channels.

Heterogeneity provided by developed model enable network and physical layer entities to be grouped according to type of interface (UMTS, Wi-Fi, Bluetooth, and WiMAX) while each group is attached to different propagation model. Single routing agent decide which interface to use, hence channel required for communication is added manually.

3.1 Intelligent network selection scheme

The proposed multi-channel heterogeneous interface architecture adopts cross layer design concept where information gathered through the different network interface is used to initiate handover of sessions to appropriate interface for service continuity in seamless roaming. The scheme select best interface for requesting application/service after implementing handoff initiation algorithm (HIA). Algorithm implemented in Handover Decision Making Module (HDMM) intelligently enable MN select best available access network.

HDMM is implemented at intermediate layer between lower and upper layers using defined metrics including data rate, received signal strength, network coverage, reliable service, mobility and security. As shown in fig. 3, evaluated metrics passed to lower layer enable fast handover decision.

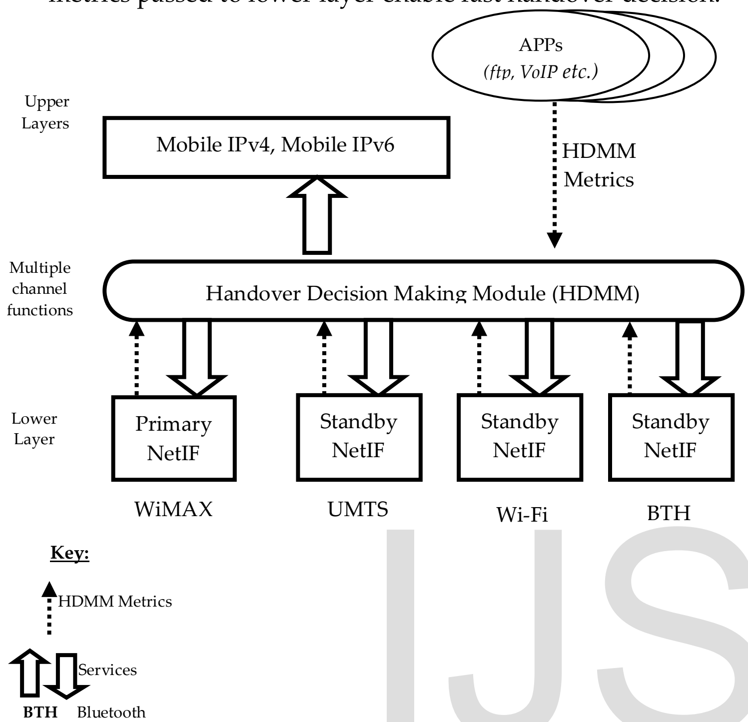

Fig. 3 Metrics for handover initiation

Using the probe process embedded in HIA, model accommodates handover decision between included interfaces. With each MN equipped with UMTS/GPRS, Bluetooth, Wi-Fi and WiMAX technologies, selected interface is enabled to work in primary or standby mode within the architecture. Only primary mode interface is activated to carry traffic stream and signalling at instant time T while other interface(s) in standby mode are allowed to receive signalling only from AP-HA.

3.2 Dynamic reconfiguration algorithm for MN

An array of channels is created and assigned to each interface included in the model. After implementing handoff initiation algorithm (HIA) shown in fig. 4, procedures for MN reconfiguration is implemented for Handover Decisions. The algorithm assist MN select network interface based on evaluation of defined metrics.

```
Simulator instproc add-channel {$indexch chan} {
$self instvar chan
for {set i 0}   {$i < 4}   {incr i} {
    set chan($index) $chan        <-  set  chan_(0)  $chan
    }                                 } else {
  ….                                  set  chan_(1)  $chan
                                      } else {
                                      set  chan_(2)  $chan
Simulator instproc get-mitf {$self set mitf $val}
$self instvar mitf
        if { [info exists chan] } {
        if { [info exists mitf ] } {
         return $mitf } else {
        return ""
        }
  }
}
…
```

Fig. 4: Handover Algorithm for heterogeneous multiple interface

4 IMPLEMENTATION AND RESULTS

Simulation developed with NS 2.35 has Access Points (APs) as base stations (BSs) scattered on an area of 500mx500m to provide over-the-air interface to wireless clients. Implementing the multi-channel multiple interface architecture in NS 2.35 provides support for UMTS, IEEE 802.11, 802.15 and WiMAX technologies. Modifications for developed model were done at two levels of OTCL configuration and C++ data handling to include:

- support for multiple access channels on each interface
- modification to routing agent for transport efficiency
- functions defined for network interface switching
- provision for mobility within simulated area

These consist of changes to ns-lib.tcl and ns-mobilenode.tcl. Variable (*mitf*) defined has parameters representing number of interfaces while set chan($index) assign channels to selected interface. *Node-config* procedure is modified by an array of channels created and assigned to each interface. *Add-interface* procedure is added to scenario script to update MN with other interface included. Routing agent attached to corresponding link layer via procedure *add-target-rtagent* creates dedicated ARP table for each interface. At the C++ level, changes on channel.cc, mac-cdma_2000, mac-802_11, mac-802_15 and mac-802_16 files enable packets to be received by appropriate interface.

Routing protocol AOMDV, characterised with multipath feature supports the included heterogeneous interface in flooding and broadcast of packets. However, ns2 lack implementation of multiple interfaces but 'switching' function defined control the handover decision while the non-adhoc routing agent direct communication between interface AP (home network agent source) when tuned to different wireless channels assigned to each interface. The radio coverage is made partially overlapped for all interfaces.

The multi-channel heterogeneous interface model is implemented such that anytime an interface is activated as

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primary user of AP, other interfaces goes to standby (as secondary user of the spectrum). With this notion of intelligence, any current interface on standby terminate (deactivate) data traffic on previously activated interface. This handover decision based on HIA evaluated for defined metrics.

With packet size of 1MB generated from AP-Home Agent (AP-HA), measurement on different interfaces is presented in Tables 1 and 2. Sending node (AP-HA) is tuned to different interface by reconfiguration procedure embedded in the algorithm. Measurements were taken on an average of three simulations each for TCP agent of 1MB attached to MN, while movement around simulation scenario was enabled. TCP-sink generate/send ACK packets after transmission of the ftp application via tcp agent.

Table 1: Packet delivery Throughput

Simulation Time	Wi-Fi (kbps)	UMTS (kbps)	BTH (kbps)	WiMAX (kbps)
10	960	950	980	960
40	950	930	890	940
60	940	900	500	960
150	930	890	80	920
180	900	895	24	930
240	850	880	8	950
300	320	910	4	980
360	200	930	0.82	9850

Table 2: MN mobility and estimated packet drop

Distance of MN to AP	UMTS	Wi-Fi	BTH	WiMAX
50	50	40	20	40
100	70	50	110	60
150	100	60	500	40
230	110	70	920	80
367	105	100	966	70
430	120	150	992	50
485	90	180	996	20
500	70	300	999	15

4.2 Analysis of results

Packet delivery throughput and estimated packet Though Wi-Fi hotspots are preferred inn areas where initial entry into network are completed for drop for each interface included in the model is analysed as shown in fig.5 and 6 respectively. Practically, Wi-Fi offer more bandwidth than WiMAX but as Wi-Fi channel 802.11n defined for multiple input multi output (MIMO) applications of higher data rate, it enables peer-to-peer communication even when there is no wireless network, that is when the AP-HA is farther away from mobile node [8]. Hence, the linearly flat response while MN moves farther from AP-HA. WiMAX channel (especially 802.16e) provides wireless access to MN with much advantage over Wi-Fi in specific applications. With WiMAX characterised with mobile broadband capability, it has increased bandwidth to connect remote networks with stronger encryption offering insignificant drops in transmitted packets. Though Wi-Fi hotspots are preferred in area where initial entry into network are competed, they are unable to provide guaranteed QoS and so not suitable for applications like VoIP or IPTV, which are QoS-dependent application [9]. With ftp applications, they are also fairly suitable.

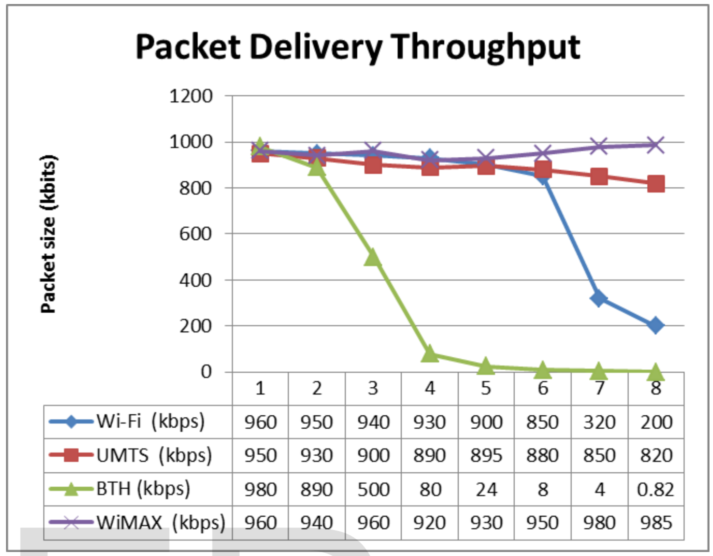

Fig. 5 Packet transmission efficiency

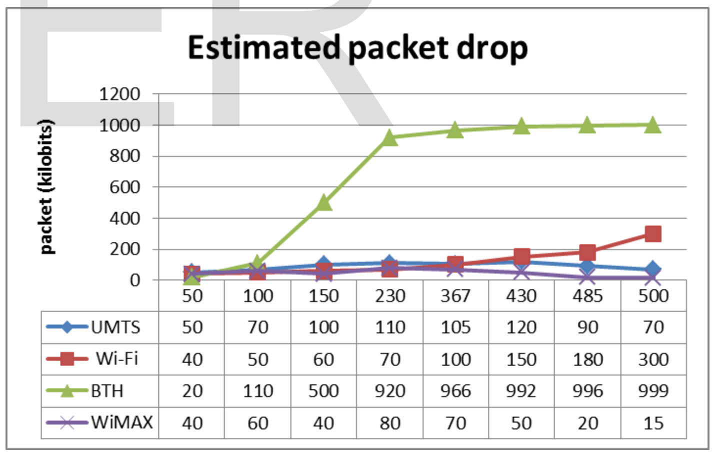

Fig. 6 Packet drop as MN moves from AP-HA

5 CONCLUSION

In this paper, we have presented a model for multi-channel heterogeneous multiple interfaces for UMTS, IEEE 802.11, 802.15 and 802.16. The proposed model is compatible transport protocols (TCP and UDP) and it adapts well with mobile IPv4 and IPv6 since mobility was provisioned for MN. The heterogeneous multiple interface model, developed and implemented in ns2.35 runs on Ubuntu Linux 12.04 to validate proposed scheme. With packet transmission rate of approximately 3kbps, results show the model effectively decrease data transmission break time to effect fast handover and subse-

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quent switch to BAAN implement *spectrum mobility*.

Moreover, heterogeneous multiple interface model is characterized with insignificant end-to-end delay suitable for continuous qualitative service and seamless roaming. This feature therefore, enables heterogeneous network use hybrid handover scheme to implement *spectrum handoff*. Operated by multiple operators, heterogeneous multiple interface model is feasible and more beneficial to mobile Internet users in future generations because both *spectrum mobility* and *spectrum handoff* is essential for service continuity in roaming.

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APPENDIX: Fig. 2: Multi-channel heterogeneous multiple interface architecture