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Abstract **-Next generation wireless network is foreseen as the combination of heterogeneous wireless networks capable of providing enhanced services to mobile users. Vertical handoff is a crucial issue in providing service to mobile users, in a heterogeneous network. To maintain continuous service during vertical handoff period, the handoff procedure should consider the noise and interference in the networks. In this article, we have proposed an algorithm based on the received signal to inference plus noise ratio (SINR) for handoff between GPRS and Wi-Fi networks. Here SINR from Wi-Fi network is converted to the equivalent SINR of the GPRS network and vice-versa, so that the handoff algorithm can have the knowledge of achievable bandwidths in both the networks. This helps in taking a handoff decision. Simulation study on handoff between GPRS and Wi-Fi networks using QualNet showed that consideration of received SINR during the vertical handoff period maintains better system throughput than considering received signal strength (RSS) as handoff criteria.**

Keywords- Vertical handof; SINR; RSS; GPRS; Wi-Fi

I. INTRODUCTION

The demand of cellular and broadband services indicates that the next generation wireless communication will be dominated by cellular and broadband services. The 3rd generation cellular network, General packet radio Service (GPRS) [1] is capable of providing IP based voice and packet data services to mobile users. The advantage of GPRS is that, it can provide a data rate up to 115 Kbps although theoretically it is 171.2 Kbps. Moreover, resource is utilized only when data is transmitted and billing is required only for the amount of data transmitted rather than for the connection time. It operates between 900 MHz and 1900 MHz. On the other hand Wi-Fi operates over a small, local coverage area typically in 100 to 500 meters and provides 11 Mbps data rates with fall back of 1Mbps, 2 Mbps and 5.5 Mbps [2, 3] and generally uses unlicensed industrial, scientific and medical (ISM) frequency band for communication.

There is no single technology that offers at the same time low cost, high-speed, nearly universal coverage, and that suits different needs of the user. The bandwidth constraint has put up a challenge for high data rate at user level for next generation wireless integrated networks. It is difficult to provide multimedia services in low data rate GPRS network. On the other hand Wi-Fi network operates on small coverage area. Therefore a mobile station may take a handoff decision to operate on the best network service either GPRS network or Wi-Fi network depending on achievable bandwidth from both of the networks.

Vertical handoff being a handover process between two dissimilar network technologies, it becomes more challenging while the user requires services during this handoff period. Traditional handoff algorithm are usually using metrics like Received Signal Strength (RSS), carrier-to-interference ratio (CIR), signal-to-interference ratio (SIR), and bit error rate (BER) as handoff criteria [4]. Using the RSS and others as the handoff indicator, we are not achieving the best possible performance of the integrated wireless networks [5]. A handoff algorithm using Signal to Interference plus Noise Ratio (SINR) as handoff criteria is proposed in this paper. Simulation study shows that the proposed algorithm provides better throughput during the vertical handoff between GPRS and Wi-Fi network under different network condition.

The paper is organized as follows. We describe the system model for vertical handoff as well as the method to determine SINR in section 2 and proposed system integration architecture in Section 3. Simulation setup and results are discussed in section 4. Finally, section 5 gives the conclusions.

II. SYSTEM MODEL

In order to provide guaranteed QoS, the vertical handoff algorithm must be QoS aware. Traditional received signal strength (RSS) based vertical handoff algorithm cannot achieve this [4,5]. Therefore we have considered a SINR based model similar to that proposed by Yang et al [5] described in the following sections.

A. SINR based vertical handoff techniques

According to Shannon capacity formula, maximum achievable data rate R_{ij} between a user i and base station j can be given by

$$R_{ij} = W \log_2 (1+\gamma_{ij}/\Gamma) \qquad (1)$$

Where W is the bandwidth of the network, γ_{ij} is the SINR received by the user i from the base station j and Γ is the dB gap between uncoded M-QAM and channel capacity, minus the coding gain.

If R_{wf} and R_{gs} are maximum achievable data rate from Wi-Fi and GPRS respectively, then they can be represented in terms of the receiving SINR from the two networks as:

$$R_{wf} = W_{wf} \log_2(1+ \gamma_{wf}/\Gamma_{wf}) \quad (2)$$

$$R_{gs} = W_{gs} \log_2(1+ \gamma_{gs}/\Gamma_{gs}) \quad (3)$$

Where, γ_{gs} and γ_{wf} are SINR received from GPRS and Wi-Fi respectively.

Since, the data rate of both the networks are different, therefore to compare the SINR of the two network, the SINR form the source must be converted to the SINR of the destination. Thus, assuming the data rates R_{wf} R_{gs} to be equal, the relationship between the SINR of GPRS as well as Wi-Fi can be obtained as given below:

$$\gamma_{gs} = \Gamma_{gs} \left((1+ \gamma_{wf}/\Gamma_{wf})^{Wwf/Wgs} - 1\right) \quad (4)$$

Knowing the data rate from both the networks, the SINR from Wi-Fi can be converted to the equivalent SINR of GPRS using the equation (4). Now the SINR from GPRS and Wi-Fi can be compared to make the handoff decision. As soon as the equivalent SINR received from the GPRS network is less than the SINR received from the Wi-Fi network, the mobile station will handoff itself to the Wi-Fi network.

B. Determination SINR at the mobile station from GPRS and Wi-Fi networks

If γ_{ij} is the SINR received by user i from the j^{th} GPRS base station gbs_j, then

$$\gamma_{ij} = G_{ij} P_j / \left(P_B + \sum_{k \in gs, k \neq j} G_{ik} P_k\right) \quad (5)$$

Where P_j is the transmitting power of the j^{th} base station (gbs_j), G_{ij} is the channel gain between user i and gbs_j and P_B is the background noise power at user receiver end.

On the other hand, if γ_{ij} is the SINR received by i^{th} user from the j^{th} Wi-Fi access point wap_i, then

$$\gamma_{ij} = G_{ij} P_{ij} / \left(P_B + \sum_{k \in wx} G_{ik} P_k - G_{ij} P_{ij}\right) \quad (6)$$

Where P_k is the total transmitting power of wap_k, P_{ij} is the transmitting power of wap_i to user j and G_{ij} is the channel gain between user i and wap_j.

III. Integration architecture for GPRS and Wi-Fi

The proposed integration architecture of GPRS and Wi-Fi networks is shown in the Fig. 1. The corresponding network is considered to be a Wi-Fi network. The mobile station (MS) is initially attached to the base station (BS) of the GPRS network and moving from GPRS to the Wi-Fi network. Mobile switching centre (MSC) is used to transmit and receive data to and from external networks. The corresponding node (CN) from Wi-Fi network sends application data to the MS during its transition from GPRS to Wi-Fi. With the help of gateways as well as the internet, the application services from CN reach the MS anywhere anytime. The throughput in any of the network is measured in terms of the number of bits received by the MS per second.

IV. Simulation

We have used a network simulator, QualNet 4.5 [6] to carryout simulation of the proposed protocol.

A. Simulation setup

We have carried out the simulation of the vertical handoff scenario between GPRS and Wi-Fi. In our scenario, Wi-Fi operates in 2.4 GHz ISM frequency band and GPRS operates in GSM 900 frequency band ranging from 900 MHz to 1800 MHz. This simulation considers the SINR received from GPRS and Wi-Fi.

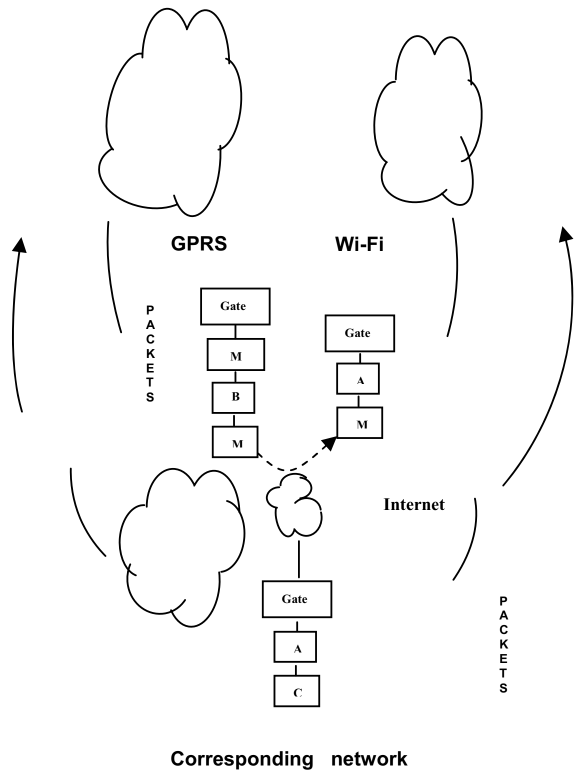

Figure 1. Proposed integration architecture of GPRS and Wi-Fi networks

In our scenario, we have considered four wireless subnets, one for Wi-Fi and the other for GPRS network, the third one for the correspondent network and the fourth for connecting these networks. The GPRS, which is under GSM technology, consists of a mobile switching centre (MSC), a base station (BS), a gateway and a mobile station (MS). The base station as well as the mobile station has a wireless link to its subnet. The base station has wired connection to the mobile switching centre which has also wired connection to the gateway.

The gateway has a wireless connection to the internet. On the other hand, Wi-Fi consists of an access point (AP) and a gateway. The third subnet consists of a correspondent node (CN), a gateway, and an access point (AP). An application of constant bit rate of data (CBR) is used to send data from the correspondent node to the mobile station. Initially the mobile station is connected with the GPRS network and it moves towards the Wi-Fi network during the simulation process.

The size of the physical terrain (in meters) in which the nodes are being simulated is in Cartesian co-ordinate. Terrain-dimensions is (1500, 1500) in square meters.

Noise power =T*k*B*f where, temperature T is 290.0 Kelvin, k is the Boltzmann constant (= 1.379 x 10-23 Joules/Kelvin), B is the bandwidth in Hz, and f is a constant called the noise factor. Here noise factor considered is to be 10. We have used BELLMANFORD routing protocol in our simulation study.

1) GPRS network parameters

Transmission power =20.0 dBm
Handover received signal strength threshold = -90.0 dBm
Channel bandwidth 200 KHz
Channel Frequency:
Downlink Frequency = 900MHz + 0.2*n
Uplink Frequency = Downlink + 45 MHz
Where n is ARFCN number and 0<n <124 for GSM 900

2) Wi-Fi network parameters

Access point transmission power = 20.0 dBm
Receiver sensitivity threshold is -91 dBm.
Frequency of channel =2.4GHz
Station-handover-received signal strength trigger (dBm) =-78.0

3) Antenna parameters

In this simulation study, Omni-directional Antenna model is used for both the networks. Gain, height and efficiency of the antenna in GPRS network are 0.0 dB, 1.5 meter and 0.8 respectively and in Wi-Fi these are 12.0dB, 10.0 meter and 0.8 respectively. Different losses associated with antenna in both the networks are mismatch loss =0.3 dB, cable loss = 0.0 dB and connection loss =0.2 dB.

B. Simulation results

We did simulation study to observe data rate and throughput for different SINR and RSS values in GPRS and Wi-Fi networks. Fig. 2 and Fig. 3 show the data rate and throughput vs. SINR/RSS values graphs respectively when the mobile user is in GPRS network. Fig. 4 and Fig. 5 shows the data rate and throughput vs. SINR/RSS values graphs respectively when the mobile user in Wi-Fi network. Simulation result shows that increase in SINR/RSS results in the increase in the data rate of the network. On the other hand, the throughput of a network depends on the number of bits received by the mobile node. The bits during transmission are affected by the background noise and interference associated with the network. Therefore, throughput depends on the strength of the SINR/RSS received by the mobile station.

Comparison result from simulation study shows that SINR based algorithm gives better data rate and throughput values in comparison to RSS based algorithm in both GPRS and Wi-Fi networks.

V. Conclusion and Future Works

Providing seamless service to mobile users during the vertical handoff period is a crucial task. SINR is the real signal strength received by a mobile station. SINR based approach is adaptable to any network condition due to the consideration of noise and interference. Therefore, we can use it to provide continuous services to mobile users as well as make more efficient handoff decisions than using a RSS based approach. Future work lies for analyzing handoff latency and reducing the number of handoffs.

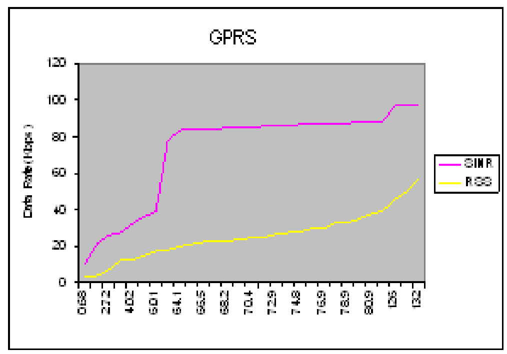

Figure 2: Data Rate(kbps) for different SINR (dBm) and RSS (dBm) values in GPRS network

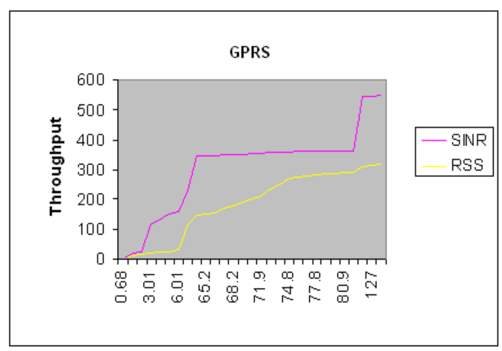

Figure3: Throughput (kbps) for different SINR (dBm) and RSS (dBm) values in GPRS network

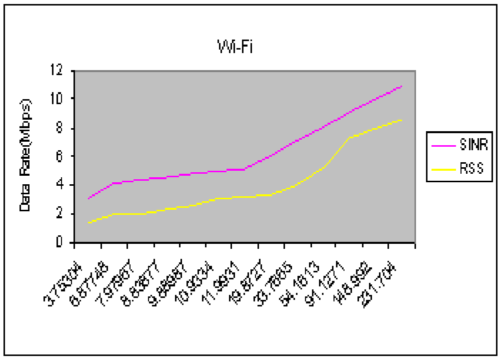

Figure4: Data Rate(kbps) for different SINR (dBm) and RSS (dBm) values in Wi-Fi network

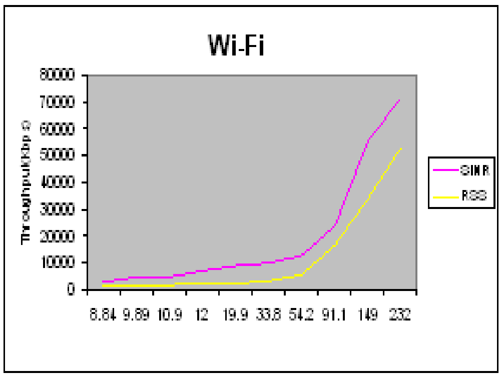

Figure5: Throughput (kbps) for different SINR(dBm) and RSS (dBm) values in Wi-Fi network

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