Comparison of Self-Adaptive Wireless Networks Using Mobile Base Stations and Mobile Access Points

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***Abstract* — We present a self-adaptive wireless LAN using *mobile access points* (MAP). We also discuss the mobile access point and a *mobile base station* (MBS) used in voice-based cellular network, focusing on the difference in PHY and MAC layers.**

The packet-level simulation, which keeps track of all packets through PHY and MAC layers, has demonstrated the proposed wireless LAN. The wireless LAN is modeled by four mobile access points optimizing themselves to eight mobile users moving randomly over a 500m × 500m area. The proposed wireless LAN achieves 41% and 40% improvement in dropped packets and outage time, respectively, compared with a wireless LAN using fixed access points.

***Index Terms* — IEEE 802.11, cellular network, mobile, self-adaptive, wireless LAN**

I. Introduction

A *totally mobile* network, where both base stations and users are all mobile, is motivated by the need for the rapid deployment of infrastructure. Autonomous mobile base stations enable self-adaptation of this type of network.

The *mobile base station* (MBS) has been studied from various perspectives. The navigation algorithm and call handoff [1], the channel allocation [2], and the mobility planning [3] were examined. However, the previous works were all based on voice-based CDMA systems. In this work, a packet-based wireless LAN using *mobile access points* (MAP) is presented and compared with a voice-based cellular network using mobile base stations.

In addition, we discuss the difference between the mobile base station and the mobile access point in the PHY and MAC layers. Due to the lack of packet-level simulation in cellular networks, the only outage time is used for performance metric.

In conventional wireless network, voice-based traffic is sensitive to delay and stays in relatively short queue. However, data traffic is robust to latency and should have error-free transmission mechanism through automatic retransmit request (ARQ). In our simulation, the UDP packet, real-time traffic similar to voice, is transmitted, but our next work will include the simulation with non-real-time data traffic.

Our ultimate goal is to build the software-defined radio (SDR) capable of configuring its PHY layer, including topology, antenna directivity, transmit power, and etc. As the first step, we present how adding the mobility into wireless access points affects the network throughput.

The network model is described with the simulation configuration in Section II. The navigation algorithm and the packet-level simulation results are presented in Section III and IV, respectively. Finally, Section V concludes with future work.

II. Network Model and Simulation Setup

The simulation setup is depicted in Fig. 1. The network is modeled by one central base station, four access points, and eight mobile users. The central base station is fixed in the center of 500m × 500m area and the access points are either fixed or mobile depending on scenarios. IEEE 802.11 WLAN protocol is used through all simulations. The physical layer (PHY) is configured to restrict the coverage range of access points to 100m in order to force the partial coverage over the area.

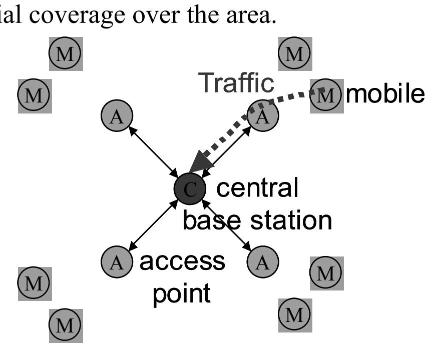

Fig. 1. Simulation setup – C, A, and M denote one central base station, four access points, and eight users, respectively.

The movement pattern of eight mobile users is created by CMU mobile module in ns-2 [4]. First, a mobile node moves linearly from one to other place at a constant speed. Next, the node stops for one second, then move to other place at different constant speed. The speed is randomly chosen ranging from 3 to 20 m/sec. For fair comparison, the same movement plan is used for all scenarios. At t = 10 sec, all users start sending UDP packets (= 500 bits) at a rate of 10 kbps, to the central base station via an access point. The simulation ends at t = 250 sec.

Three scenarios are simulated and compared.

1) Mobile Access Point (MAP) with fixed users
2) Fixed Access Point (FAP) with mobile users
3) Mobile Access Point (MAP) with mobile users

The first scenario simulates that mobile access points can optimize their location to the randomly distributed users. The second and third ones demonstrate that the wireless LAN can reconfigure itself to mobile users and improve the dropped packets and the outage time.

III. Mobile Base Station and Mobile Access Point

The comparison of the mobile base station and the mobile access point focuses on the PHY and MAC layers.

A. Physical (PHY) Layer

Although a transmitted signal in cellular networks may reach up to several kilometers, the coverage range of an access point is generally limited to hundreds of meters. In practice, a cellular network should take care of users on high-speed vehicles, but a wireless LAN usually assumes stationary users. In addition, the available channel of a wireless LAN is much fewer than that of a cellular network. There are only three nonoverlapping channels in IEEE 802.11b/g protocol.

B. Medium Access Control (MAC) Layer

The direct sequence CDMA, the most popular cellular networks, should have very good power control because of the *near-far effect*. However, carrier-sensing-multiple-access (CSMA) of wireless LANs allows only one trans-mission at a time, eliminating the need for power control. But, CSMA protocol may suffer from the *hidden and exposed terminal* problems, when two or more transmitters are sending packets to a receiver at the same time.

IV. Navigation Planning

In general, the performance metrics for network topology planning include coverage, channel interference, and handoff. Similarly, these performance metrics are used as the cost function of topology optimization. In the previous work, center of gravity (CoG), social potential fields (SPF), and gradient descent were investigated [1].

The above navigation planning requires the geometric information that is collected in the centralized or distributed manner. The centralized planning needs global geometric information offered by Global Positioning System (GPS), whereas the distributed planning uses the only local geometric information to optimize the topology. The local geometric information may be acquired by the combination of triangle methods and directional antennas.

The central base station is assumed to collect and distribute the geometric information offered by GPS in this simulation. Therefore, in this simulation every access points share all geometric information in the centralized manner. Center of gravity takes the average of each axis of the location of neighbor users, and then sets it to the destination of a mobile access point. This optimization is conducted every one second.

In addition to the geometric information, the cost function may include total path, transmit power, latency, and congestion. This task is challenging and left for future work as it includes multiple layers in communications – physical, data link, network, and transport.

V. Simulation Results

All simulations employing access points are performed by ns-2 [4], using *Center of Gravity* (CoG) for navigation algorithm and the model and scenarios described in section II. The previous work performed simulations employing mobile base stations [1].

Fig. 2 shows that all packets are transmitted successfully without outage, because mobile access points can move to the geometric center of the fixed neighbor users by CoG navigation before the users start sending at t = 10 seconds. The first simulation demonstrates the self-planning of topology through the navigation algorithm.

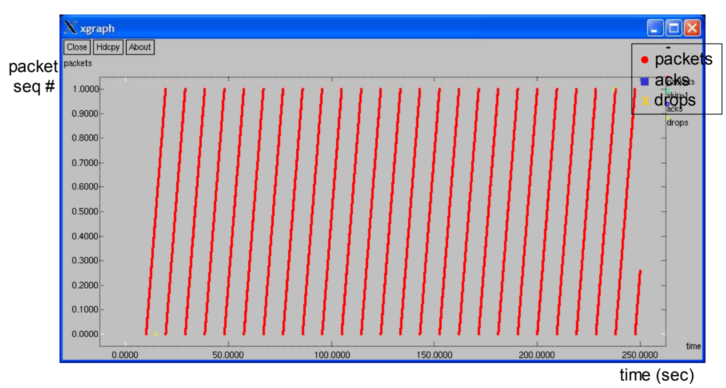

Fig. 2. Simulation of packet data with Mobile Access Points (MAP) and fixed users

As shown in Fig. 3, once mobile users get out of range, outage occurs and packets are dropped. In the second simulation, mobile users are moving as described in Section II and the wireless access points are fixed at the initial position.

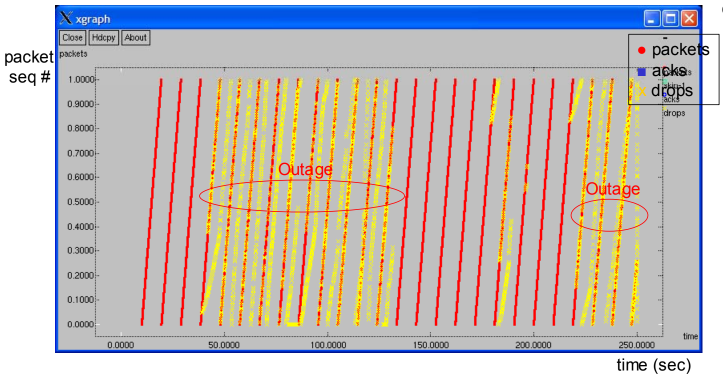

Fig. 3. Simulation of packet data with Fixed Access Points (FAP) and mobile users

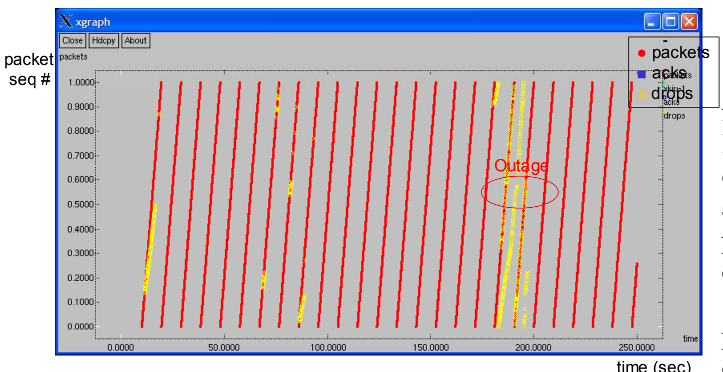

Fig. 4. Simulation of packet data with Mobile Access Points (MAP) and mobile users

Fig. 4 shows the simulation of the third scenario, where mobile users are still following as the same movement pattern as the second scenario and access points are optimizing by CoG. Compared with Fig. 3, it can be seen that outage and dropped packets are reduced significantly. Therefore, the comparison of Fig. 3 and Fig. 4 demonstrates the effectiveness of the proposed network for mobile users.

Table I summarizes the performance of wireless networks using base stations and access points, which are either fixed or mobile depending on scenarios. For the packet-level simulation for access points, all dropped and transmitted packets for all users are summed up. The result of the cellular network, which consists of 6 mobile base stations and 48 mobile users, shows 18% improvement from 73% to 60% in the outage time [1]. The wireless LAN, using mobile access points, reduces the dropped packet from 19581 to 11585 by 41% and the outage time from 50.5% to 30.3% by 40%. Obviously, introducing mobility to both access points and base stations shows the significant improvement. Note that the improvement in the wireless LAN is much larger than the cellular network.

TABLE I
COMPARISON OF NETWORK PERFORMANCE USING BASE STATIONS AND ACCESS POINTS

Scenario	Outag e	Packets	
		Drop	Transmit
Fixed Base Station	73.0%	N/A	N/A
Mobile Base Station	60.0%	N/A	N/A
Improvement	18%↓	N/A	N/A
Fixed Access Point	50.5%	19581	38400
Mobile Access Point	30.3%	11585	38400
Improvement	40%↓	41%↓	N/A

VI. CONCLUSION AND FUTURE WORK

The comparison of the mobile base station and the mobile access point is discussed in terms of the PHY and MAC layers. The packet-level simulation proves the effectiveness of introducing mobility to access points. In addition, the proposed wireless LAN using mobile access points achieves more significant improvement than the cellular network using mobile base stations.

Currently, the network simulator ns-2 has the limited physical layer models. Modeling of radio propagation channels, antennas, and RF transceivers is crucial for the accurate simulation results. These physical layer models should be developed in ns-2 and the building blocks in RF transceiver will be modeled with noise and linearity.

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