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Service-Oriented Wifi Connectivity Maintenance with a Mobile AP

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***Abstract*—We consider the problem of providing continuous wireless connectivity to mobile Wi-Fi users via a mobile access point (MAP). In traditional infrastructure Wi-Fi networks, mobile users may experience poor or no connectivity when they are away from an access point (AP) and/or there is an interfering obstacle in between. The connectivity is affected by the factors such as type of data traffic (like interactive, responsive, timely, and non-critical) or ambient conditions e.g., interference and distraction/refraction due to obstacles. In proposed approach, the quality of the connection is measured by the value of received signal strength (RSSI). If RSSI at a client is lower than a pre-specified threshold, a MAP acts as a relay node, and forwards the traffic from the AP to mobile clients instead of direct communication. MAP dynamically relocates in order to satisfy a service oriented level of connection quality. In our approach, the routing is performed at the MAC layer, so the network layer is unaware of the change in routing path. Simulation results demonstrate that the proposed approach provides continuous connectivity to the clients at the cost of a low end-to-end average delay.**

Keywords—connectivity; wireless; service-oriented approach; mobile access point

I. Introduction

IEEE 802.11 based wireless networking (called Wi-Fi in popular press) is now a standard feature of all modern wireless devices. Wi-Fi networks are realized through deployment of huge number of wireless network access points also called APs spread in different environments (public, business, residential). An AP is a short range routing device that wirelessly connects in-range mobile users with the internet. AP advertises its presence by sending out beacons identified by Service Set IDs (SSID). In active probing, WLAN clients wait for the AP response after broadcasting probe requests. Meanwhile, in passive probing, WLAN clients wait for beacons from an AP. The authentication and association processes ensue after the discovery of a WLAN [1].

The quality of reception at a client depends on the received signal strength which further depends on the location of the client and the ambient interference. Roughly speaking, the farther the client is from an AP, the weaker is the signal the client receives. When a client moves away from an AP and/or there is an obstacle in between, the received signal strength decreases, and the client may either observe a low connection rate or may get completely disconnected. To remain connected to the internet, clients either connect with nearby access points having stronger connectivity, or switch to different network like LTE. Clients do not bother technology and environmental limitations and demands uninterrupted and continuous use of the applications on their devices. Several approaches have been proposed in the literature to provide continuous connectivity to mobile users. Efficient deployment of APs can better support the mobility of users and ensure their connectivity [2][3][4]. Connected robots to keep uninterrupted connections with mobile users is just another work in this domain using different approach by freezing the movement of mobile robots if further movement can cause network partition [5]. However, these approaches do not consider the individual service quality of mobile users in terms of their connectivity requirements. Furthermore, these works have high computational overhead due to the fact that the locations of the clients need to be continuously tracked. Our work on the other hand improves the current state-of-the-art by developing a service-oriented approach to provide dependable connectivity without requiring explicit locations of the clients. By service-oriented approach, we refer to the fact that different data services have distinct Quality-of-Service requirements. The proposed work best fits for AP-sparse scenarios where it is difficult to deploy multiple APs because of lack of infrastructure or the environment is too much congested and full of static or moving obstacles.

We propose a system where a stationary AP along with a mobile AP (MAP) provides a level of connectivity to the clients that satisfies their individual service requirements. MAP is just like a Wi-Fi relay, repeater, or range extender. MAP use same SSID as AP, so clients can communicate in the same way with MAP as they were communicating with AP. A MAP could be a mobile robot having a repeater device mounted on it. It takes data from AP and rebroadcast it in the air with its own power. The clients suffering from poor connectivity use MAP as an intermediate node for relaying the packets to/from AP. MAP always positioned it to relay clients' data with reasonable connectivity levels. Calculating MAP position is a critical task depending on many parameters. We develop a simple-to-implement mobility algorithm for positioning of MAP by taking into account RSSI of the links between clients and AP, application service types run by clients and RSSI between MAP and AP. The algorithm dynamically computes the direction of movement of MAP to optimize the quality of connections of roaming clients. Our approach does not require the positions of clients; rather it takes into account the received signal strength and the types of service the clients are using. In order to realistically model Wi-Fi signal propagation behavior, detailed channel conditions are taken into consideration in the developed simulation

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framework. We extensively analyze our proposed approach, and determine that the use of MAP significantly increases throughput by maintaining a reasonable service-oriented connectivity.

The rest of the paper is organized as follows. Section 2 explains the related work from literature. Section 3 presents our proposed methodology to achieve persistent connectivity for mobile clients using proposed mobility algorithm and how to set RSSI thresholds according to service type. Section 4 explains about simulation environment, metrics used to analyze the proposed system and achieved results. In section 5, we discussed about different aspects of proposed approach and future work. Section 6 concludes the whole work.

II. RELATED WORK

Over the past several years, connectivity maintenance for mobile users especially in Wi-Fi based networks has become important area of research, as more and more mobile devices are connected wirelessly. There are number of factors responsible for poor Wi-Fi connectivity including but not limited to unplanned AP deployment, environmental factors (interference, diffraction, refraction,), and propagation losses due to obstacles.

[5] Proposed a three step connectivity maintenance algorithm SCAN which determines when nodes should cease their movement in order to preserve connectivity while maintaining reasonable area coverage. The process is distributed in a sense that individual nodes use only 2-hop topology information to cease their movement. SCAN was implemented in hardware having claimed to maintain full connectivity over 99% of the time. However, it only considers presence and absence of connectivity rather than received signal strengths.

To support Wi-Fi mobility, in [2] idea of simultaneously connecting to multiple APs on the same/different channels has been proposed. Mobile nodes connect to all the APs they see without any explicit L2 handover, thereby increasing capacity and reliability of certain Wi-Fi flavors (802.11a/b/g). The traffic is only directed to most efficient AP decided by congestion controller in their proposed scheme. However, their approach is causes delay and jitter due to switching between APs.

In [3], the concept of virtual access points is used to support wireless LAN mobility. To do so, mobile stations are considered fixed while virtual access points are assumed to be mobile. Virtual APs are responsible to carry routing, cache and available modulation information of their associated clients. The decision of switching between access points is taken by RSSI values. When RSSI of one AP is larger than other AP, the mobile station is associated with the AP having larger RSSI value. The approach in [3] uses single radio channel which could lead to interference and collision. To anticipate connectivity loss with an access point, [6] developed a method to predict the decrease in signal quality against a threshold. Algorithm anticipates the decrease in connectivity and can trigger to use a repeater/relay to forward data to respective clients depend on the signal value. The threshold value is set as the minimum RSS value required to run an interactive service.

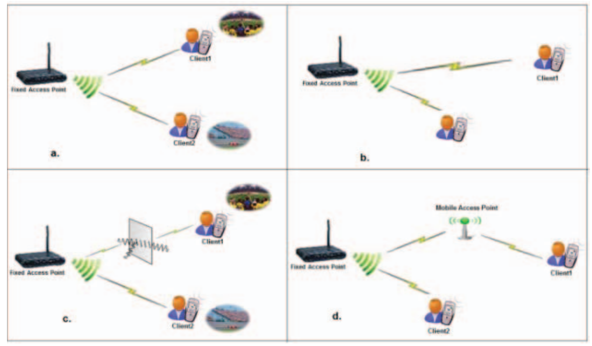

Fig. 1. Observed scenarios and proposed solution

Inefficient and unplanned AP deployment is one of the main reasons of receiving insufficient RSSI and lack of Wi-Fi mobility support. To efficiently utilize Wi-Fi services for mobile users, [4] proposed access point deployment algorithm, which takes into account the statistical mobility patterns of users with the aim to increase continuous user coverage and minimize AP deployment cost. To model a realistic obstacle scenario, authors in [7] present a deterministic obstacle shadowing model considering real channel conditions. An accurate environmental representation of obstacle is important to simulate real world channel propagations [18].

Our approach is distinct from described approaches in a manner that we consider the service oriented approach in providing continuous connectivity. Our approach does not require the clients' positions and combines RSSI with service type as parameters to decide on the connectivity levels i.e. either user have enough bandwidth to run applications or some actions to be taken to provide sufficient connectivity levels.

III. METHODOLOGY

In a typical Wi-Fi network, mobile clients usually run multiple applications simultaneously. Each application may have different bandwidth and delay requirements causing different applications to effect differently upon signal degradation. Our approach considers the effects of the mobility of the clients and the shadowing due to obstacles on different service requirements and aims to sustain connectivity levels by relaying data from AP to clients via MAP. Figure 1 depicts scenarios when two clients are streaming data from the same AP. In Fig. 1(a), both the clients are within good connectivity range and receiving a reliable service. However, Figure. 1(b) and 1(c) illustrates the cases where clients receive poor connectivity either when moves to a faraway position or encountering with an obstacle. Finally, Figure 1(d) depicts our proposed scheme which makes use of a MAP at a suitable position in between client1 and the AP where MAP acts as a relay and forwards the traffic to client1 with reasonable signal strength. With increased number of disrupted clients, MAP chose a position where it can relay the data with reasonable service-oriented connectivity requirements. By the inclusion of a MAP, we aim to improve the overall quality of the connections between the AP and its clients. To provide wireless connectivity, it is important to consider the characteristics of wireless medium in different environments. Wireless medium is prone to interference and other environmental factors. In the following subsection, we briefly

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explain the effect of different types of services and the ambient channel conditions on signal strength and bandwidth requirements.

TABLE I. SERVICE CATEGORIES WITH QOS REQUIREMENTS

Service Category/Metric	Delay	Packet Loss
Interactive	< 1 Second	<3%
Responsive	~ 2 seconds	~4%
Timely	~ 10 seconds	~5%
Non-critical	> 10 seconds	~7%

A. Service-oriented Approach

The extent to which a client is affected by its mobility depends on the type of application or service it is using. Each service type has its own QoS requirements. A voice-over-IP application, for instance, does not tolerate even very minor delays. On the other hand, non-critical applications can survive packet loss and longer delays. Typically, application services can broadly be classified into 1). Interactive like conversational audio/video services, 2). Responsive like voice messaging, e-commerce, 3). Timely like streaming audio/video services and 4). Non-critical like email, fax. Among the factors that differentiate QoS for each service type include but not limited to packet loss, delay and bandwidth [8].

Table 1 shows different service categories along with QoS requirements in terms of packet loss and delay. A mobile client using non-critical application will be affected less by the signal degradation as compared to the mobile client using connection sensitive applications. For simplicity, we divide the said four service types into two groups; interactively-responsive and timely-noncritical.

B. Effects of environmental factors on Received Signal Strength Indicator (RSSI)

Wireless signal in 802.11 spectrum propagates in an unpredictable manner subject to cross-talk, multipath propagation, fading, and interference. These effects are only exacerbated by unknown features of the operational environment. Multipath effects are caused by walls and obstacles, while fading increases in the presence of RF-absorbent surfaces. In such a hostile environment, the relative positions of two nodes do not provide the necessary information on whether they will be connected or not [5].

RSSI is a measurement of the power present in a received radio signal [20]. It represents the usable strength of the radio waves expressed in decibels (dBs), where 0db represents highest and -120db shows lowest signal strength. However, the range can vary depending on the chip vendor e.g. Atheros and Cisco use 0~-127 and 0~-100 ranges respectively. Roughly -45db~-85db is considered normal range for wireless communication. Anything below -85db is generally unusable, and over -50db can be considered perfect [9].

Outdoor environment has less distractions and obstacles as compared to an indoor environment where a wireless medium face a large number of distractions (building material, furniture, and people). A client may lose connectivity even by moving a few steps to certain direction in an indoor environment.

Obstacles change the behavior of the signal propagation in an unpredictable way. Different obstacle models are available in literature to take into account the effects of different types of obstacles [12]. Table 2 summarizes the loss in signal strengths of different materials in dBs. We consider the wall as obstacle in our simulations. A typical RSSI measurement includes the energy from the intended transmission, external noise, and the energy from concurrent interfering transmissions. In order to avoid temporary peaks in the RSSI value of received signals, most Wi-Fi cards maintain a weighted moving average [10]:

TABLE II. TYPICAL ATTENUATION FOR BUILDING MATERIALS AT 2.4

Material	**Loss (dB) 2.4GHz**
Interior Drywall	3-4
Cubicle Wall	2-5
Wood door	3-4
Concrete wall	6-18
Glass window	2-3
Double-pane coated glass	13
Steel door	13-19
Free space	0.24 per ft
Tree	0.15 per ft

$$RSSInew\ ave = RSSIold\ ave.X + RSSIlast\ measured.Y$$

To read the non-negative received signal quality at client, we used the following conversion into signal quality:

$$SQ = 2 * (RSSI + 100) \qquad (1)$$

We expressed the relationship between RSSI and signal quality roughly as

$$if\ RSSI \geq -50db$$

It is considered 100% signal quality and

$$if\ RSSI \leq -100db$$

It is considered 0% signal quality.

Where SQ shows signal quality in percent.

RSSI is not the only available parameter to measure signal quality. In previous works [11], few other approaches have also been used namely SINR (Signal-to-Interference-plus-Noise Ratio), PDR (Packet-Delivery Ratio), and BER (Bit-Error Rate) [11]. Selecting a specific signal behavior related metric depends on application requirements.

In proposed scheme, MAP acts as a relay whenever the RSSI becomes less than a certain threshold. We assume that MAP resides somewhere in between the AP and clients and is within connectivity range from anywhere in the network. Roughly speaking, a decrease in signal strength is either because a client is moving away from its AP or there is an obstacle (wall in our simulations) located between the AP and the client. As demonstrated in the simulation experiments given in the subsequent section, our proposed approach provides consistent network connectivity irrespective of the client movement.

C. RSSI Threshold Calculation

To set a limit on drop in RSSI value, we used RSSI threshold to determine the decrease in received signal strength. Determining a reasonable threshold value is a critical task when considering distinct service requirements. To set the threshold, we divide the services into two pairs namely interactively-responsive as pair1 and timely-noncritical as pair2 services. Minimum RSSI requirement for pair1 and pair2 is set as R_{min1} and R_{min2} respectively. Clients checks RSSI of each received packet against a specified threshold, we call this threshold thrsh_basic which has -60dBm as the default value. We chose -60dBm as basic value by realizing the fact that -65dBm is considered minimum required signal value to satisfy an interactive application. Client may run multiple applications. As, each packet contains the service type information, there is no need to separate and distinguish multiple applications. It is common sense that among multiple applications, the unacceptable decrease in RSSI will be for the one having higher RSS demands like for interactive applications. If RSSI value is find less than thrsh_basic, an alert message is sent to the MAP. This alert message contains information about clients RSSI value and service type. At this point, we do not bother about multiple applications run by clients and their distinct RSSI requirements. Clients check against threshold which is set against highest signal strength requirements irrespective of which application is running. This approach is taken to switch the computation burden from clients to MAP.

TABLE III. MINIMUM SIGNAL STRENGTHS AGAINST SERVICE TYPES

	Minimum required RSSI	Service type	Service type value
R_{min1}	-65dBm	{Interactive, Responsive}	2
R_{min2}	-80dBm	{Timely, Noncritical}	1

D. Role of Mobile Access Point

As explained in the introduction section, MAP is a mobile robot like device having ability to reposition itself to *work as relay. MAP to work as relay or repeater must have* three basic components namely two antennas and one amplifier. One antenna mount the signal to amplifier, while another antenna rebroadcast the amplified signal. Initially, MAP position is set in the middle of defined network area to make it reachable by all the clients resides anywhere in the network and to remain in a good connectivity range with AP. MAP does not need to relay all on the way packets. The packets whose destination address matches the client's IP address for which MAP has received alert message or has run mobility algorithm are relayed. Upon reception of alert message from client, MAP checks the RSSI- service mapping table to decide on the particular service requirement. Table 3 shows the minimum required RSSI for each service category. We set -65dBm for pair1 and -80dBm for pair2 as minimum required signal strengths. These thresholds are set based on minimum requirement to satisfy specific service category [19]. If the received service type matches with service type against received RSSI in the mapping table. Moreover, if RSSI value is less than R_{min1} or R_{min2}, depending on the type of service the packets were destined for, MAP takes decision of running mobility algorithm to determine next position where it can move and relay the data between AP and clients with reasonable signal strength. To minimize the time and complexity, RSSI is first checked against R_{min2}. This is because R_{min2} is set minimum to satisfy non-critical applications. If RSSI is less than R_{min2}, MAP will run mobility algorithm without any further delay. If received RSSI in alert message is greater than Rmin2, then MAP check the value against Rmin1. If RSSI at alert message is less than Rmin1 according to service category, then mobility algorithm is run by MAP, otherwise, the message is ignored. In the following subsection, we briefly explain the mobility algorithm run by MAP to make mobility decisions.

IV. MOBILITY ALGORITHM

In order to ensure satisfactory connectivity levels, our approach does not require locations of client to be known. It simply make use of the readily available RSSI and service type set given in Table 1. These parameters are used to decide on the use of MAP as a relay, and if so, to reposition it to maximize the quality of client connection. The basic idea of mobility algorithm is based on harmonic mean (HM) of RSSI and service type as input parameters. HM is the reciprocal of the athematic mean of the reciprocals and for real positive numbers x_1, x_2, $x_3 \ldots x_n$, it is defined as

$$HM = \frac{n}{\frac{1}{x_1}+\frac{1}{x_2}+\cdots+\frac{1}{x_n}}$$

HM has the ability to fairly consider each parameter based on its value. MAP's RSSI must be higher enough to support client's higher RSS demands. Client's RSSI is the one received in alert message. Finally, service type value is set from scale 1-2 where 2 represent the highest scale. MAP runs the proposed mobility algorithm to find a location to move to where it can relay the clients' data with reasonable connectivity levels. Figure 2 provides the pseudocode of a basic version of our proposed mobility algorithm. We briefly explain different parameters description here.

A. Mobility Algorithm Prameters

Proposed mobility algorithm takes certain input parametrs to work on and calculates MAP's next position. These parameters are:

1) Client RSSI: Clients check RSS of each received packet against a threshold (thrsh_basic). Threshold is set in a way to satisfy maximum RSS requirements.

2) Service Type: Clients check RSS of each received packet against a threshold (thrsh_basic). We divide the services into two categories as interactively-responsive service set with weightage 2 and timely-noncritical service set having weightage 1. Each client sends respective service type along RSSI in its alert message.

3) MAP RSSI: It is also important that while working as relay, MAP should always be connected with AP with highest possible signal strength. Before running mobility algorithm for repositioning, MAP sends a beacon message to AP and gets its RSSI in Ack message from AP. MAP use this RSSI as an input parameter in mobility algorithm to ensure its connectivity with AP.

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B. Bechmark Value Calculation

At the time of initialization, MAP calculates benchmark value with whom mobility algorithm's calculated value is compared to make decision of MAP movement. The benchmark value is calculated using parameter values which satisfy minimum requirement of interactive service (with service type value of 2). We used -70dBm as a minimum required value to satisfy an interactive service to ensure maintaining minimum required connectivity level. Every time a new value is calculated by mobility algorithm, it is check against this bench mark value and if calculated value is less than benchmark value, MAP moves to next position, otherwise remain stay at current position. The algorithm is explained in figure 2 where MAP in a 2D space decides on moving its adjacent positions of x-1, y or x, y-1 or x+1, y or x, y+1.

The time MAP takes to run mobility algorithm and actually move to new position is in order of seconds. We observed 4~10 seconds delay in the overall process. After moving to new position, if MAP receives new alert messages and finds to run mobility algorithm, it uses previously used parameter values of client RSSI and service type along with newly received alert message values as input parameters in the mobility algorithm. It is obvious that MAP recalculates its RSSI every time it runs mobility algorithm.

V. Simulation and Results

We implemented our algorithm over a realistic channel model in ns-3 simulation software [13]. Clients' during simulation experience signal degradation because of moving away from the point of connectivity. Client nodes are free to move, they roam around the simulation area and may experience signal degradation. Clients also can experience an obstacle in its way. Obstacles create profound effect on how client gets the signal passing through the obstacle. Table 2 depicts the effect of obstacles on signal quality. with whom clients connect to, a MAP to relay data traffic between the clients and a fixed AP and varying number of mobile clients (5,10,15) using different middle of network area for better connectivity with AP and clients. Each client check each received packet against thrsh_basic. When a client finds its RSSI values less than data services. Initially, we set the MAP position exactly at the thrsh_basic, it sends a beacon message to MAP contains received RSSI value and service type category value. In our simulations, clients are free to move within the simulation area. We set the movement of the clients according to the random waypoint mobility model [14].

In order to simulate the realistic wireless environment, we use Friis propagation loss model. We used Adaptive auto rate fallback (AARF) [16][17] to adjust the rate of the connection based on the connection quality. Two retransmissions per packet are permitted in the simulation. Clients run one or multiple data services from two service categories explained in previous section. To increase the reliability of results obtained, five iterations of each simulation are run, where each iteration are run for 120 seconds. The results are then averaged for five iterations. To evaluate the feasibility of proposed approach, throughput and delay are used as performance metrics. The proposed approach is compared with SCAN [3] and baseline approach i.e. when mobile clients are attached directly to the AP and when client get connected to AP via MAP. SCAN provides connectivity maintenance by freezing the movement of mobile robots. In SCAN, a proactive mobility algorithm decides on the situations which can cause network portioning and freeze further ccc movement of robots. However, SCAN considers only the absence and presence of connectivity. If robots are communicating irrespective of connectivity levels, are considered connected. Our scheme on the other hand considers individual service connectivity demands along with realistic channel conditions. Simulation results reveal that use of MAP as relay and by considering service oriented connectivity requirements, we achieved better throughput and were able to maintain reasonable connectivity with a minor delay. Figure 4 shows the parameters we used in our simulations.

MAP Mobility Algorithm

MAP performs following procedure to calculate its new position.

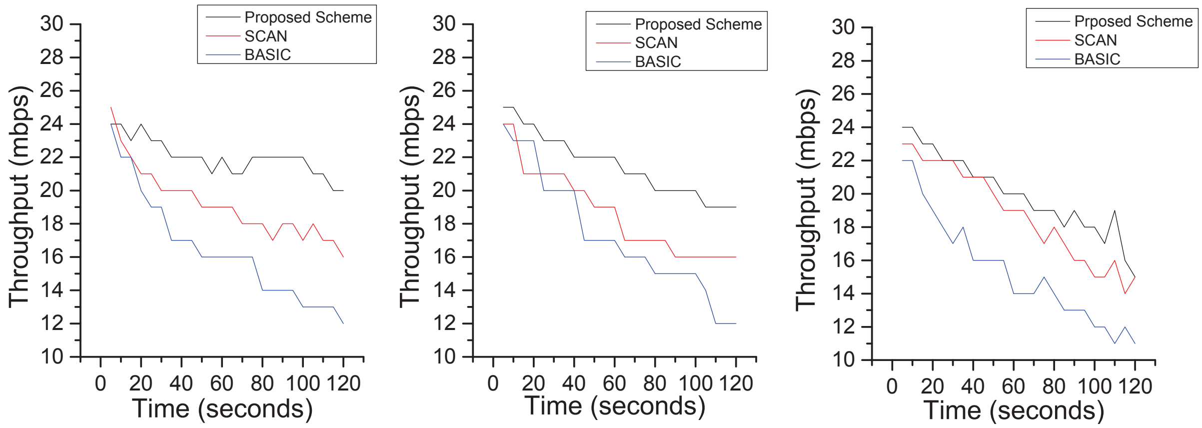
```
1:  MAP position at time t=0 is (x, y) in a 2D space.
2:  For each client request, to decide on new position, MAP
    checks for (x+1, y), (x- 1,y), (x, y+1), (x, y-1) possible
    positions.
3:  Check received alert message from client
4:  If CLIENT_RSS<= R_min2 then
5:  Send HELLO message to AP to get MAP_RSSI
6:  Calculate Harmonic Mean having parameters;
    CLIENT_RSSI, MAP_RSSI and service type value
7:    if HM value is < benchmark value then
8:    MAP moves to (x+1, y) position
9:      else stay at (x, y) position
10:   else check service-RSSI table
11:     If need to run mobility algorithm then
12:     Go to step 7
13:       else stay at (x, y) position
14: Repeat step 7 For all 2D directions
```

Fig. 2. Basic version of mobility algorithm run by MAP

A. Throughput

When disconnected or distorted, client experiences packet loss which leads to more retransmitted packets and hence cause decrease in the throughput. AARF adjusts its rate based on the number of transmission failures and consecutive successful transmissions. According to [16], AARF allows highest transmission rate after 10 consecutive successful transmissions.

Fig 3 shows the average throughput of proposed scheme compared with SCAN [5] and basic approach. We observed the decrease in throughput with increased number of clients over time. The effects are observed with 5, 10 and 15 mobile users. Figure 3.a shows the throughput with 5 clients. The proposed scheme with 5 clients' shows highest throughput against SCAN and basic approach. In proposed scheme, less number of clients needed the support of MAP in relaying packets when got disconnected or distorted. Also, MAP had to consider less number and less frequent simultaneous clients to entertain for relaying data, which increased its potion accuracy and decreased algorithm running and position changing frequency.



(a) (b) (c)

Fig. 3. Throughput against number of clients (a). 5 clients (b). 10 clients (c). 15 clients

PARAMETER	VALUE
NO. OF NODES	5,10,15
ACTIVE AREA	50M^2
WLAN STANDARD	802.11G
RATE CONTROL ALGORITHM	AARF
PROPAGATION LOSS MODEL	FRIIS PROPAGATION LOSS MODEL
MOBILITY MODEL	RANDOMWAYPOINT2D MOBILITY MODEL
TYPE OF OBSTACLE	WALL
FADING MODEL	OBSTACLE SHADOWING
TRANSMIT POWER	7.5DBM

Fig. 4. Simulation Parameters

In Figure 3.b and 3.c, when the number of clients increased to 10 and 15, we see a gradual small decrease in overall throughput of proposed scheme. Initially, the throughput is increasing over time with each different number of clients. This is due to less mobility and less traffic in the network. We see smaller intervals throughout the timeline when throughput got decreased. These intervals are observed more frequently in figure 3.b and 3.c with increased number of clients. The decrease in throughput during these intervals is because client(s) during these intervals were far off from AP and were waiting for MAP to relay data to them. Overall, proposed scheme show higher throughput against competing strategies when compared against SCAN and basic approach.

Meanwhile, from figure 3, we also see better throughput of SCAN [5] as compared to basic approach. In SCAN, clients freeze their movement if connectivity is compromised due to their movement, which avoids network partitioning and loss of packets and retransmissions. Overall in SCAN, we observed a kind of stable throughput with different number of clients. Figure 3.a, 3.b and 4.c shows the throughput in SCAN with varying number of clients. Compared with proposed and basic approach, SCAN shows lower throughput than proposed approach and higher throughput than basic approach. This is because SCAN does not consider intermediate connectivity levels; rather, clients are assumed to be either connected or disconnected. However, SCAN shows better throughput than basic approach by proactively protecting connected clients from disconnection due to their mobility. Throughput of basic approach is lowest overall as shown in figure 3.a, 3.b and 3.c. clients' movements are random and when disconnected or distorted, packet reception is effected, which caused increased retransmissions and lower the data rate by AARF. Role of MAP in proposed approach is key to increased throughput and performance of the proposed approach in providing continuous connectivity. Entertaining fewer nodes and less frequent position changes increases the overall throughput of the system.

Table 4 shows the number of simultaneous disconnected or distorted clients MAP had to consider for relaying. The table shows increase in simultaneous disconnected/distorted clients with increase in number of clients. The minimum number of simultaneous disconnected/distorted client was one in case of five clients, while maximum number of simultaneous disconnected/distorted clients were observed seven in case of fifteen clients.

B. Delay

Delay of a packet is calculated as difference in time that the first bit of the packet is received minus the time the last bit of a packet was sent. The delay includes transmission delay, propagation delay and queuing delay. In our simulations, we consider queuing delay as zero. The delay is calculated as

$$Delay = D_p + D_t$$

Where D_p stands for propagation delay and D_t represents transmission delay. Propagation delay is affected by many factors including but not limited to distance between sender and receiver, environmental factors like refraction, diffraction, and path loss.

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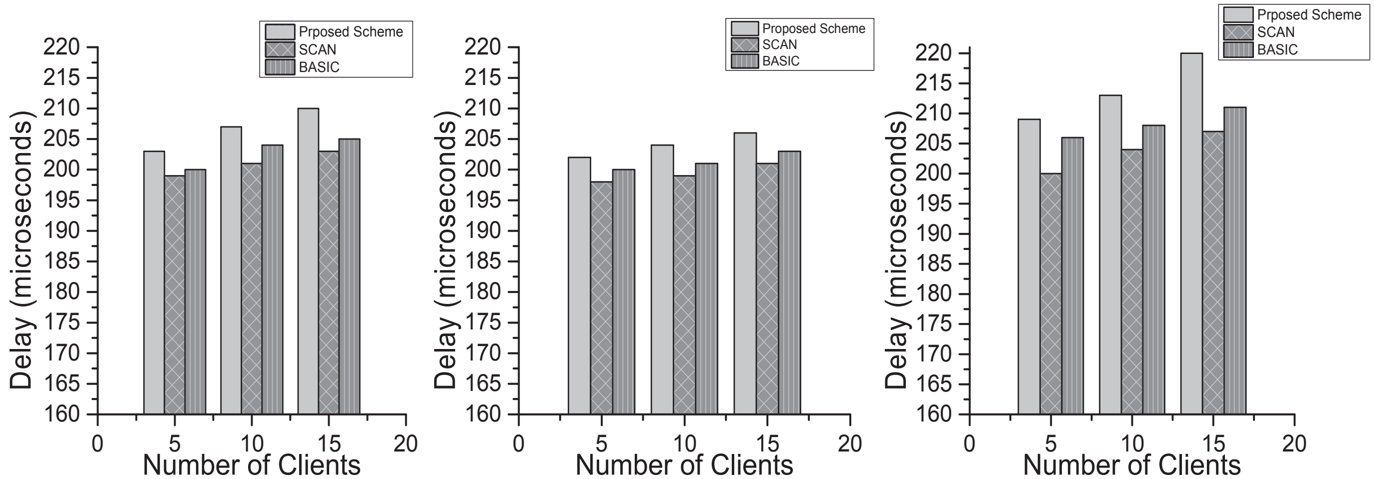

Fig. 5. Packet delay with different number of clients and service types a). non-critical service b). non-critical and interactive service c). interactive service

Transmission delay on the other hand is not affected by distance between communicating nodes but on length of the packet and data rate of the channel. In our simulations, the transmission delay is in the order of microseconds as we kept our packet size small enough (1024 bytes). However, major part of delay is caused by propagation of packets. We used Friis propagation loss model which considers distance between communicating nodes into account and calculates a quadratic path loss as it occurs in free space [15]. In the scenario when clients are directly connected to the AP, the delay is calculated as packets are sent from the sender to the receiver with no change in path. However, in proposed scheme, the inclusion of MAP increase the delay of packet reception to some extent, as it has to pass through two interfaces as relay node, i.e., from AP to MAP and then from MAP to clients.

Figure 5 shows per packet delay averaged over ten simulation iterations each run for 300 seconds. At the time of simulation, we were not sure about the relationship between number of clients and delay and how different services affect this delay. We ran three different simulation sets; 1). All the clients used simple noncritical service, 2). Some clients used interactive and some used non critical service, 3). All the clients used interactive service. The delay in each service category is compared among proposed scheme, SCAN [5] and basic approach. We compute the delay using same 5, 10 and 15 numbers of clients. Simulation results show variations in delay using different services with different number of clients. Figure 5.a shows the delay with 5 clients using non-critical service. Initial simulation results show almost same delay in all the three approaches. This could be due to the fact that at start clients were not mobile. With the passage of time, the clients started moving and some of the clients' got distorted.

The increase in distance between sender and receiver cause increase in propagation delay. In case of proposed scheme, MAP relay the packets from AP to far-away clients. Overall, SCAN's delay is least in all, as it considers full connectivity between clients. However, with the increase in number of clients the delay in proposed scheme is increased. This is due to the fact that Figure 5.b and 5.c shows the delay in three approaches having mix and interactive services respectively. Delay in all the three approaches is increased with increased number of clients and with increase in service quality. From the figure, we can make a relationship between delay, number of clients and the type of services clients are running.

Proposed scheme's slight increase in delay is due to the fact that MAP has to configure and run mobility algorithm and to actually move to new location. Simplified mobility algorithm and careful motion planning can significantly reduce this delay and can increase throughput. We worked on mobility algorithm to make it as simple as possible. However, developing optimized algorithms for motion planning are out of scope of this work. Depending on the scenario, MAP can follow any motion pattern e.g. as given in [5].

Analyzing and comparing relationship between RSSI, throughput and number of nodes.

TABLE IV. MIN./MAX. NO OF SIMULTANIOUSLY DISCONNECTED/DISTORTED CLIENST IN PROPOSED SCHEME

No. of Clients	Min. simultaneous disctd/distorted clients	Max. simultaneous disctd/distorted clients
5	1	2
10	2	4
15	2	7

We also observed the relationship between delay, different service types and number of clients. In this section, we analyzed the effect of RSSI on throughput and how number of clients can affect the received signal strength. To see the overall network behavior, we averaged RSSI and throughput values. Table 5 shows the observed RSSI and throughput for 5, 10 and 15 number of clients compared among proposed scheme, SCAN and basic approach. According to table, we see increased throughput for 5 clients with reasonable RSSI to run an interactive service.

In case of proposed approach, we however see negligible throughput difference. The reason to this little variation could be that the 10 clients were less mobile as compared to 5 clients and/or there was service type usage difference during the execution.

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TABLE V. RELATIONSHIP AND COMPARISON RSSI AND THROUGHPUT BETWEEN PROPOSED, SCAN, AND BASIC SCHEME

	Avg. RSSI with 5 clients	Avg. RSSI with 10 clients	Avg. RSSI with 15clients	Avg. Throughput with 5 clients	Avg. Throughput with 10 clients	Avg. Throughput with 15clients
Proposed Scheme	-50dBm	-53dBm	-62dBm	25Mbps	24Mbps	20Mbps
SCAN	-58dBm	-63dBm	-76dBm	20Mbps	19Mbps	16Mbps
BASIC	-63dBm	-75dBm	-84dBm	16Mbps	13Mbps	12Mbps

The throughput and RSSI value is decreased with more number of clients, as more clients are mobile and can disconnect/distract. SCAN and basic approach on the other hand show more variations in received signal strength values. In case of basic approach, throughput for 10 and 15 clients is less varied for the same reason as explained for proposed scheme. From the table, we see a direct relationship between number of clients, throughput and signal strength values. Decrease in RSS result in decreased throughput.

On the other hand, increase in number of mobile clients effects received RSSI and hence throughput. This is because number of input parameters get increased and it is not easy for mobility algorithm to fulfill the exact requirement of each parameter. MAP has to consider more simultaneous distorted clients for connectivity. Figure 5.b and 5.c shows the delay in three approaches for 10 and 15 number of clients.

VI. DISCUSSION AND FUTURE WORK

In our simulations, we considered providing continuous connectivity to 5, 10 and 15 users' simultaneously. Our mobility algorithm considers different factors while making decision for next MAP position where it works as relay. The proposed scheme significantly increases the throughput. However, the inclusion of MAP as relay slightly increases overall delay as packets have to pass through multiple interfaces.

This delay can be minimize by applying more optimized mobility algorithms and applying sophisticated buffering for streaming services at client. It is expected that increase in number of clients will make the situation more complex and difficult to fulfill bandwidth requirements of all the connected mobile clients' simultaneously. More connected clients will decrease the overall throughput and delay. In future work, we aim to consider providing connectivity to more than 30 users with more complex parameters like more realistic and complex propagation models and considering different type of obstacles. In the current work, we did not consider the effects of fast fading and occasionally drop in RSSI.

In the extended version of this work, we aim to use a regression/analytical model to use past RSSI values to analyze the signal behavior to differentiate actual decrease in signal strength from fast fading. We also aim to simulate indoor and outdoor environments separately and model the differences in connectivity considering more realistic channel conditions.

VII. CONCLUSION

In this paper, we aim to provide continuous Wi-Fi connectivity to mobile clients who suffer from poor or no connectivity either due to their movement or encountering obstacle(s). Our approach provides service oriented connectivity by considering the type of service client's use. When clients experience low connectivity, MAP reposition itself to works as relay node and forwards the traffic towards clients to ensure required connectivity levels (based on data service client is using). We proposed a mobility algorithm to calculate MAP's new position based on service requirements. Simulation results show that our approach was able to assure connectivity to mobile clients with a negligible time overhead.

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