AN EFFICIENT WI-FI INTERNET ACCESS FOR MOVING VEHICLES USING SWIMMING SCHEME

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Abstract—Accessing internet from moving vehicles is demanding and has been rapidly growing. Due to mobile detonation, the overloading issue of cellular networks is increasing. So, the Wi-Fi based accessing is considered to offload cellular networks that are a promising technology for internet access. But, it poses many problems in highly dynamic vehicular environments for Wi-Fi networks. In order to solve this problem, this paper proposes a better scheme, namely, SWIMMING to support the Wi-Fi based internet access for moving vehicles. For this purpose, a group of Access Points (APs) are employed to communicate with the client. In this scheme, the AP in the group accomplishes the delivery ratio to the client once the transmission is succeed. To avoid high packet loss, all APs present in the group are configured with same MAC and IP addresses. Moreover, the link reliability is enhanced by exploiting the AP diversity and opportunistic transmission. In this paper, the probability of successful transmission is improved by delivering the packet at two stages in downlink communications. The main advantages of this work are, it improves the efficiency of channel utilization, it provides seamless roaming within the coverage of the entire network, and it overwhels the issues of unreliable links and unstable connections. The experimental results evaluate the performance of the proposed system in terms of Packet Delivery Ratio (PDR), throughput and packet loss.

Index Terms—ACK Detection, Access Point (AP), Downlink communication, Internet Access, SWIMMING, Uplink communication and Wi-Fi.

1. INTRODUCTION

The demand for internet access from moving vehicles has grown sharply in recent days with the penetration of portable devices. The commuters and passengers would like to access the internet by using their smart phones or other portable devices for browsing the web, accessing e-mails, making VoIP calls, playing online games, watching video programs and other purposes. Nowadays, the cellular networks such as 3G, 4G or GPRS provide pervasive internet connection with high cost. So, the cellular networks are insufficient for surging large amount of data from internet enabled portable devices. Moreover, it suffers due to the overload of subscribing and mobile data growth. IEEE 802.11 based Wi-Fi is another technology to provide wireless connectivity. The Wi-Fi hotspots are organized broadly and compactly in many cities. The Wi-Fi has many advantages such as,

- Lower cost
- Higher peak throughput

So, it is more suitable solution for cellular traffic offloading. Still, it is a challenging task due to the following reasons,

- The channel condition in a vehicular environment harsh due to the severe multi-path fading, noise and interference that results in high packet loss rate.
- Then, the client moves at a vehicular speed, so it is extremely difficult for it to be always associated with most appropriate AP.
- Moreover, a client may suffer from frequent connection disruptions due to the limited coverage of single AP.

In order to overcome all these issues, the SWIMMING scheme is proposed in this paper to support seamless and an efficient Wi-Fi based internet access from moving vehicles. In SWIMMING, a group of APs are employed to communicate with a client. If any APs in the groups provides successful delivery to client, the transmission will be succeed. Such AP diversity and opportunistic transmission are exploited to overcome these issues of high packet loss and data overhead. It will be achieved by configuring all APs with same MAC and IP addresses. An example scenario for Wi-Fi based internet accessing scheme is shown in Fig 1. When the client wants to transmit a packet to the virtual AP for uplink communication, the multiple APs within its transmission range are able to receive it. So, the transmission will be successful as long as at least one AP receives the packet without any loss. After that, the AP which received the packet will sends an acknowledgement (ACK) frame. Here, the SWIMMING operates in a group unicast mode.
The remaining sections of this paper are organized as follows: Section II reviews some of the existing works related to Wi-Fi based internet accessing schemes for moving vehicles. Section III provides the detailed description for the overall SWIMMING based Wi-Fi internet accessing system. Section IV presents the performance results of the proposed system. Finally, this paper is concluded in Section V.

2. RELATED WORK

This section presents some of the existing works related to Wi-Fi based internet access for moving vehicles. Pin, et al [1] proposed a new architecture, namely, SWIMMING for accessing the Wi-Fi based internet from moving vehicles. For this purpose, all Access Points (Aps) were configured by using the same MAC and IP addresses. The conventional ACK decoding scheme was utilized to avoid the collisions of ACKs from different APs. Cheng, et al [2] focused the problem of Wi-Fi offloading in vehicular communication environments. The authors also discussed about the challenges and identified the issues related to drive-thru internet access and an effectiveness of vehicular Wi-Fi offloading. Moreover, a comprehensive review of the mobile data Wi-Fi offloading in vehicular communication environments was provided in this paper. Hou, et al [3] suggested an integrated transport layer solution for vehicular network access. The main intention of this paper was to move load from the expensive 3G network to the less expensive Wi-Fi network without hurting the user experience. Da and Yeo [4] proposed a new representative based prefetching mechanism to utilize the wireless bandwidth provided by APs. Mouton, et al [5] evaluated the performance of various handover approaches in a real commercial deployment. The authors utilized a second wireless interface to obtain a make-before-break handovers and they identified some issues in providing completely seamless connectivity for moving vehicles.

Cespedes, et al [6] identified the problem of IP mobility and its specific requirements for vehicular scenarios. Here, the Network Mobility Basic Support (NEMO-BS) protocol was developed to enable IP mobility for infotainment and internet based applications. Bai, et al [7] analyzed the characteristics of Dedicated Short Communications (DSRC) under realistic vehicular environments. The authors investigated the impact of both uncontrollable environment factors and controllable radio parameters for analyzing DSRC characteristics. Nishanthi and Sivakumar [8] developed a SWIMMING mechanism to support seamless and efficient Wi-Fi based internet access for moving vehicles. Here, the AP multicast group was maintained dynamically to follow the moving client. Bychkovsky, et al [9] studied the proliferation of Wi-Fi networks in residential areas in and around cities. In this paper, three possible optimizations were explored such as,

- Connection initiation timing
- Fairness
- Aggregation bandwidth over multiple APs

Alam, et al [10] introduced an analytical model to measure the workloads of different subsystems involved in the Social Internet of Things (SIoT) process. Zheng, et al [11] suggested a proficient algorithm for coverage verification and logarithmic factor approximation to verify whether a given deployment provides an alpha coverage. The performance of this approach was evaluated by using the data of real road networks and compared them with both uniform and non-uniform AP placement techniques. Deshpande, et al [12] designed a Multi-Radio Multi-Vehicle (MRMV) system for metro Wi-Fi access. It has the following features,

- It used multiple Wi-Fi interfaces with APs to mask handoff latencies.
- It was able to use other MRMV clients and to avoid coverage holes.

Zheng, et al [13] presented a new metric, namely, contact opportunity as a characterization of roadside Wi-Fi deployment. It was closely related to the quality of data service that a mobile user might experience, when driving through the network. The proposed method ensured a required level of contact opportunity at a minimum cost with the help of sub-modular optimization technique. Hare, et al [14] described the deployment of vehicular internet access service on public transit buses. The authors provided different insights acquired during the process of deployment and running a continuous service with real users. Berezin, et al [15] analyzed the characteristics of Wi-Fi coverage and connectivity of mobile users by using different mobility speeds with varying AP settings. In this paper, the Wi-Fi coverage, connection, internet access session and disconnection duration were measured to evaluate the performance of the proposed system.

3. PROPOSED METHOD

This section presents the detailed description for the proposed SWIMMING based Wi-Fi access system. The main intention of this work is to increase the generation of moving vehicles for accessing the Wi-Fi internet.
Fig 2. Overall flow of the proposed system

The overall process of the proposed system is shown in Fig 2, which includes the following stages:

- Network formation
- Uplink communication
- Downlink communication
- Verification of ACK detection
- Performance analysis

3.1 ARCHITECTURE OF SWIMMING

We consider the scenario as shown in Fig 1 for describing the proposed SWIMMING based system. Here, the road is completely covered by open Wi-Fi APs and the coverage of each AP is overlapped with other. It is armed using two interfaces such as,

- Access link
- Backhaul link

The access link uses wired or wireless medium to form a backhaul and this link can be either a Local Area Network (LAN) or a wireless mesh network. Here, the backhaul connects to the internet through a gateway. It is assumed that both bandwidth and reliability of backhaul links are higher than the access links. Moreover, the packet loss in backhaul is negligible. In this paper, the traffic between clients and internet is taken into consideration. The backhaul is structured into a tree topology with the gateway as the root and APs as leaves. Here, the AP diversity and opportunistic transmission are mainly designed to improve the reliability of transmission. The identical configuration of all APs has one important advantage, it eliminates both the IP layer and AMC layer handoffs. Moreover, the re-associations are avoided and the network connection will not be disrupted even if an AP crashes. In this environment, all APs are operate on the same wireless channel. Generally, the SWIMMING is easily extensible to multi-channel deployment. Because, the APs are equipped with multiple Wi-Fi radios and these radios are configured with the help of various non-overlapping channels.

The advantages of SWIMMING are,

- The link reliability is improved and the loss of packets are reduced by exploiting the AP diversity and opportunistic transmission.
- Here, the adverse effect of multiple ACKs are eliminated by designing an ACK detection function. It ensures that the ACK based rate control mechanisms can be adopted for improving the efficiency of the channel utilization.
- It eliminates the layer 2 and layer 3 handoffs of the mobile client and it achieves the seamless roaming within the coverage of the entire network by configuring all APs with same settings.
- Moreover, it increases the probability of successful transmissions by using the two-stage packet delivery in downlink communications.

3.2 UPLINK COMMUNICATION

In uplink communication, two important processes such as, acknowledgement detection and transmission redundancy are performed.

3.2.1 ACK Detection

The acknowledgement (ACK) format is specified in IEEE 802.11 standard as shown in Fig 3. Here, 14 byte ACK is generated by different APS that are exactly same for some data packet of a client. The weak signal is dropped by the filter of the receiver under the first condition. The ACK overlapping is shown in Fig 3.

The overlapping signals can be decoded based on the following conditions:
1. The signal strength is considerably higher than the other signal.
2. The arrival time difference is less than the OFDM guard interval.

In this paper, the ACK detection scheme is proposed to avoid retransmissions caused by ACK collisions. Once the Wi-Fi node receives the packet without any loss, it will send an acknowledgement to the corresponding sender after a short inter-frame space as specified in IEEE 802.11.

3.2.2 Transmission Redundancy

The diversity of multiple APs is exploited to receive a data frame from sender with the help of multiple APs. An extra overhead is introduced, if all copies of the same packet are forwarded to the gateway. To measure the overhead of transmission, a metric, namely, Transmission Redundancy Ratio (TRR) is used. It is defined as the fraction of redundant transmissions by an effective transmission times. A redundancy removal mechanism is also proposed to minimize the TRR. If an intermediate node in the backhaul receives a packet successfully, it simply forwards it or drops if it is a duplicate packet. It is important to check the identity of the packet to determine whether the packet has been delivered before.

3.3 DOWNLINK COMMUNICATION

An AP diversity and opportunistic transmission are leveraged to improve the transmission reliability. Moreover, a group of APs are employed to serve the client. Here, the packets are sent to this AP using multicast for reducing the transmission overhead. Consequently, the multicast group is established for each client to enable the downlink communication. The process of downlink communication is shown in Fig 5.

If the AP forwards the packet successfully, it automatically removes it from the buffer. Then, it sends the notification to each multicast group member to remove the corresponding packets. So, all APs in the multicast group are automatically synchronized and it does not store any obsolete packets for the client. Moreover, the AP sends a keep-alive message to this group for receiving the uplink packet. If an AP does not receive any uplink packet or keep-alive message of client for uplink communication, it will leave from this multicast group. When the AP leaves from the group, it will automatically delete all packets buffered for the client. To verify the effectiveness of ACK detection, the verification process is performed.

4. PERFORMANCE ANALYSIS

This section presents the performance results of the proposed SWIMMING based internet accessing system. The results are analyzed and evaluated in terms of,
- Average delay
- Packet Delivery Ratio (PDR)
- Throughput

Moreover, the proposed SWIMMING technique is compared with the existing T-Unicast technique for proving the better performance of the proposed system. From this analysis, it is proved that the proposed SWIMMING gives the best results.

4.1 NETWORK FORMATION

Initially, the network is formed with set of nodes with APs and Gateways that is shown Fig 6, where the violet colored point denotes the Gateways, green colored point indicates two APs and red colored point indicates the moving vehicles.
4.2 AVERAGE DELAY

The average delay is defined as the time between the message generation and its transfer to the final receiver. It is estimated based on the average of all the received messages with acknowledgements and it must be equal to 0. Fig 7 illustrates the average delay of the existing T-Unicast and proposed SWIMMING systems.

Figure 6. Network formation

4.3 PACKET DELIVERY RATIO

Packet Delivery Ratio (PDR) is the ratio between the number of packets transmitted by a traffic source and the number of packets received by a traffic sink. It measures the loss rate as seen by transport protocols, and it characterizes both the correctness and efficiency of routing protocols. Fig 8 shows the comparison graph between the existing T-Unicast and the proposed SWIMMING techniques. In this graph, the x-axis represents the number of clients and y-axis represents the packet delivery ratio. It is calculated as follows,

\[
PDR = \frac{\text{Number of packets received}}{\text{Number of packets transmitted}} \times 100
\]

Figure 7. Average delay for existing and proposed system

4.4 THROUGHPUT

Throughput is defined as the average rate of effectively transferred data packets over the communication range. It can be measured in terms of bits or data packets per second. The proposed SWIMMING technique efficiently achieved high throughput rate than the existing T-Unicast method. Throughput for existing and proposed methods with respect to different speed is shown in Fig 9 and with respect to various APs is shown in Fig 10.

Figure 8. Packet Delivery Ratio (PDR) for existing and proposed systems

Figure 9. Throughput for existing and proposed methods with respect to different speed

Figure 10. Throughput for existing and proposed methods with respect to various APs
5. CONCLUSION AND FUTURE WORK

This paper proposed a new SWIMMING based Wi-Fi internet accessing scheme. This paper focuses to provide Wi-Fi internet connectivity to moving vehicles that supports the broadband data rates. It contains an advanced protocols in both uplink and downlink communications. In this scheme, the seamless roaming of clients is successfully attained and the channel utilization is radically enhanced. The major advantages of this technique are, it enhances the link reliability and reduces the packet loss by exploiting both the AP diversity and opportunistic transmission. Here, an ACK detection function was designed to remove the adverse effect of multiple ACKs. It ensures that the ACK based rate control mechanisms can be adopted in SWIMMING to enhance the efficiency of channel utilization. The experimental results are analyzed and evaluated for both existing T-Unicast and proposed SWIMMING techniques in terms of Packet Delivery Ratio (PDR), throughput and average delay. When compared to the existing technique, the proposed SWIMMING provides the best results.

REFERENCES

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