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Performance Based Routing Protocol Mechanism for Wireless Ad-hoc Network

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Abstract- The use of TCP for several Internet applications today mandates its adoption as a transport layer protocol in heterogeneous networks comprised of both wire-line and wireless links. However, the congestion control mechanisms of TCP cause the losses over the wireless channel to be perceived as an indication of congestion and the data transfer rate of TCP to be adversely impacted. The solutions that have been proposed over the years to troubleshoot the problem have their share of drawbacks. The use of adaptive link layer techniques in emerging wireless technologies opens up the possibility of a cross-layer approach for TCP performance enhancement. In our work we outline an optimization framework based on the congestion control dynamics of a bulk-transfer TCP flow. By identifying TCP window evolution patterns in the dynamics, we develop a generic optimization framework for throughput enhancement via adaptive link layer measures. We demonstrate the performance increase on application of the optimization approach. We next investigate a cross-layer multi-hop routing approach based on link connectivity assessment in mobile ad-hoc networks. We suggest a framework for proactive enhancements to the Optimized Link State Routing (OLSR) protocol and implement the proposed measures within the protocol format. We finally address efficient packet scheduling for multiple-interface wireless systems. The demand for bandwidth aggregation in such systems has resulted in a pronounced need for appropriate packet scheduling measures. In this thesis we can achieve reduction in buffer lengths, packet delays, multi-user interference, and device energy consumption.

Keywords- Wireless Network, OLSR Protocol, TCP.

I. INTRODUCTION

The fast emerging trends in the wireless industry are influencing our lifestyles, driving businesses and synergistically thriving with research efforts. As cell phones, laptops, and PDAs have become increasingly popular, the demand for ubiquitous wireless access has risen tremendously. Infrastructure for wireless connectivity is getting deployed in every imaginable place in our lives: homes, offices, public libraries, cafes, university campuses and even in trains and aircrafts. Up until recently, wireless local area networking products have prevailed alongside the cellular infrastructure as the primary wireless coverage sources. With the recent emergence of wireless metropolitan area networking standards, broadband wireless access is garnering significant interest as an alternative to cable networks and DSL. System design efforts for the next generation wireless networks are being aimed at efficient utilization of resources like spectrum and energy. The fluctuations in the quality of the wireless channel, however, pose a challenge to design and development. Attempts for enhanced channel reliability do not necessarily entail optimum networking efficiency. Through this work, we investigate a vision of enhanced system performance via adaptation to radio conditions [1] and [2].

We present the demarcation of networking functionality into layers, and provide an overview of the Transmission Control Protocol (TCP). We then introduce a cross-layer design approach for wireless systems and discuss some prevailing trends in wireless networking. A multitude of wireless systems have become widely deployed for providing wireless connectivity. These systems vary in the supported applications, provisioned data rates, resilience to user mobility, portability of associated equipment, and ease of deployment.

The autonomous and distributed nature of an ad-hoc network makes its deployment economical and scalable, but presents a challenge to secure communication and distributed medium access. The nodes in an ad-hoc network may be mobile in which case the dynamism in the network topology makes routing difficult. An efficient routing protocol needs to adapt to variation in network connectivity with time. The networking functionality is usually divided into distinct modules or layers. For instance, the OSI architecture model developed by the International Organization for Standardization (ISO) is comprised of seven layers. Layer-1 is called the physical layer and involves transmissions of data bits on to the physical medium. Layer-2, the data link layer, is subdivided into the Medium Access Control (MAC) that controls access and encodes data into valid signaling format for the physical layer, and Logical Link Control (LLC) that provides an interface to layer-3, the networking layer. The networking layer is entrusted the job of routing data in the network and has functionality relating to address assignment and forwarding methods. The transport layer (layer-4) is responsible for end-end error recovery and flow control. It provides for transparent data transfer between two communicating users. The layer-5, called the session layer, manages and coordinates data connections between users.

The presentation layer (layer-6) performs data translation between a user application and the network, and vice versa. The application layer (layer-7) provides services and functions to support a multitude of user applications. Wireless networking is confronted with the challenge of

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channel unreliability. The wireless energy attenuates over distance due to a phenomenon called path loss. There also are variations in the signal due to blockage by obstructing objects like buildings. This is referred to as shadowing. Again, rapid variations in signal result from a large number of multipath components reaching the receiver. The transmitter and receive mobility causes spatiotemporal variation of the wireless channel. Moreover, in a multi-user environment, interference can cause signal detection errors at the receiver [1] and [5].

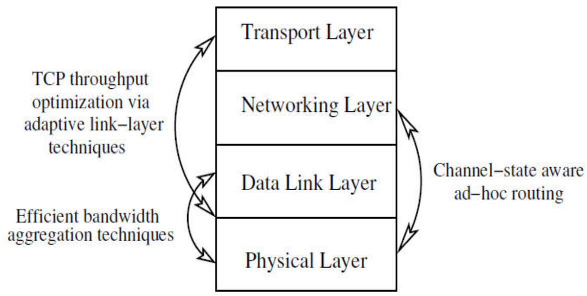

Figure 1: Cross-layer design issues.

Ad-hoc networking constitutes another important facet of a wireless system design. While ad-hoc networks have conventionally been associated with communication in combat fields and sites of disaster, they are increasingly being deployed for facilitating communication in homes, offices, conferences sites and among vehicles. Several important ad-hoc networking applications are associated with scenarios here the node are mobile. However, routing in a mobile ad-hoc network is a challenge due to the associated dynamism in network topology. For instance, a communication scenario with vehicles on the move presents routing with challenge due to variations in driving conditions and vehicular mobility patters [3] and [11].

II. BACKGROUND

With the proliferation in use of wireless devices over past several years, there has been a growing interest for access to mobile Internet and web-based applications. TCP being a popular transport layer protocol for the Internet is responsible for transfer of Internet data in heterogeneous networks comprised of wired and wireless links. However, it was originally designed to operate well in wire-line environments where the channel conditions are highly reliable and data losses are primarily due to congestion. It thus faces operational challenges in wireless scenarios that are characterized by sporadic losses and disconnections.

TCP perceives the losses on a wireless link to be an indication of network congestion and invokes its congestion control mechanisms. This leads to a reduction in data transfer rate and impairment of the end-to-end throughput. The solutions that have been proposed over the past several years to counter the problem include end-to-end schemes, split connection approaches and TCP aware link layer protocols. The end-to-end schemes involve making changes to TCP to make it capable of distinguishing between congestion and wireless link losses. The Explicit Loss Notification (ELN) is one such end-to-end mechanism. The ELN option is added to TCP acknowledgements. When a segment is dropped on a wireless link, the acknowledgements for the subsequent segments are marked to identify that a non-congestion loss has occurred. On receiving such an acknowledgement, that sender can perform retransmission of the lost segment without invoking congestion control mechanisms. Although end-to-end schemes preserve TCP semantics, these require modifications to TCP. The infeasibility of Internet wide deployment of such changes poses a severe restriction to the practical utility of such solutions. The split-connection approaches divide the TCP connection between the sender and receiver into two distinct connections - one between the sender and the BS and the other between the BS and the receiver. A specialized protocol tuned to the wireless environment can be used for the connection that extends over the wireless hop. The split-connection approach is however marred by increased processing overheads, violation of end-to-end semantics of TCP acknowledgements, and slow, complicated handoffs.

Enhanced link layer reliability has been investigated as a mechanism to improve TCP performance in wireless scenarios. However link layer designs that are TCP unaware cannot efficiently shield TCP from the wireless losses and are also associated with increased rate and delay variability.

On the other hand, approaches on line of the SNOOP protocol represent a TCP aware link layer design. While SNOOP preserves the end-to-end semantics of TCP and does not require any changes to TCP implementation, it has its own share of limitations. It cannot be used for the case when TCP data and ACKs do not both traverse through the BS (or AP). The protocol also has overhead associated with SNOOP cache maintenance. Moreover, during the interim period between handoffs, the BS (or AP) to which the handoff is occurring cannot snoop on any acknowledge ements sent from the mobile host. Another disadvantage of the SNOOP protocol is its inability to function when TCP headers are encrypted. None of the aforementioned solutions encompass or utilize adaptivity of wireless systems features like FEC, transmission power, and multiple transmission modes. There have been some recent efforts to examine adaptive link layer measures for TCP throughput optimization. The authors adopt standard steady state TCP throughput expressions and perform optimization by adapting the coding rate, number of retransmission attempts and transmission power. The TCP dynamics and congestion control mechanisms are not considered in the work. We argue that for performance optimization, the link layer needs to be adaptive to the instantaneous dynamics of a TCP flow. In the model of TCP's congestion avoidance dynamics and evaluate adaptive power control measures for throughput enhancement in a simplified scenario [3] and [4].

A. *Congestion Control Dynamics of TCP-*

The dynamics of a steady state bulk-transfer TCP flow. TCP dynamics can be described via its window size evolution and congestion events. The congestion window designates the limit on maximum amount of data (or the number of segments) that can be transmitted without waiting for an acknowledgement (ACK). The receiver advertises a similar limit on outstanding data based on its buffer limitations. At any time, a TCP sender can send as many unacknowledged segments as allowed by the minimum of congestion and receiver windows. The slow start and congestion avoidance algorithms determine the evolution of the congestion window and are used by a TCP sender to control the amount of unacknowledged data being injected

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into the network. During the slow start phase, TCP increments the congestion window by one segment for each ACK that acknowledges new data. This entails doubling of the window every Round Trip Time (RTT). The congestion avoidance phase on the other hand is marked by an increment of one in window size every RTT. The slow start phase governs the dynamics until the window size reaches a threshold (called the slow start threshold beyond which congestion avoidance takes over. The idea is to make TCP probe for network capacity by increasing the window size first aggressively and then cautiously. In case of a Timeout (TO) or Triple Duplicate (TD) loss indication, the value of the threshold is set to the minimum of 2 segments and half of the current congestion window size. At all times TCP's window size is limited by the receiver advertised window.

The TO and TD indications characterize the congestion (or loss) events of TCP. The TO indication occurs when the TCP sender is waiting for an ACK and the retransmission timer expires. TCP infers that the packet has been lost: it reduces the window size to one segment, retransmits the packet, and doubles the Retransmission Time Out (RTO) value. This retransmission procedure is repeated until the packet is ACKed and subsequently TCP window dynamics follow the slow start or congestion avoidance algorithms, depending on the values of threshold and congestion window size. The TD loss indication on the other hand is characterized by the arrival at the sender of three duplicate ACKs. A duplicate ACK is generated by the receiver in response to arrival of an out-of-order segment and bears the sequence number of the next expected in-order segment. TCP's Fast Retransmit Algorithm uses the arrival of 3 duplicated ACKs (4 ACKs with same sequence number) as an indication that a segment has been lost. Following the TD indication, TCP performs the retransmission of what appears to be the missing segment, without waiting for the retransmission timer to expire [5] and [12].

Most TCP versions today implement the above discussed congestion control algorithms. TCP Reno in addition employs Fast Recovery that enables it to recover from segment loss in a window without a timeout. TCP NewReno can recover from multiple segment losses in a window via partial acknowledgements. TCP SACK can counter multiple segment loss as well, via selective acknowledgement (SACK) mechanism. Using selective acknowledgements, the TCP receiver can inform the sender about all the segments that have been received correctly.

The sender can then retransmit the segments that have been lost. TCP SACK can employ congestion control algorithms similar to Reno, or can utilize information from its SACK options for congestion control procedures. We in our work model the slow start and congestion avoidance algorithms with maximum window size limitation and consider both TD and TO congestion events. Most of the Reno implementations today have been rendered obsolete by SACK/New Reno deployment. Hence we assume that TCP is able to recover from multiple segment losses in a window in the event of TD loss indication. A TCP flavor may implement its own fast recovery process, for instance, the one assisted by SACK options (TCP SACK) or partial ACK mechanisms. Adaptive Power Control Transmission power adaptation is desirable in wireless networks for several reasons including limiting the interference that a wireless link generates, and conserving energy for battery power limited mobile devices. The process of adjustment of power by the wireless transmitter is called power control. TCP-dynamics-based power adaptation results in significant throughput enhancement over conventional power control mechanisms while incurring the same average transmission power. The success probability of TCP segments in a wireless network can be regulated by adapting the transmission power of data frames on the wireless channel. We will see how controlling transmission power according to TCP dynamics results in significant throughput enhancement over conventional power control methods. The main objective of the present evaluation is to highlight the intuition behind the TCP throughput optimization approach. We hence restrict the assessment to a simplified scenario, and present power adaptation measures without considering a generic multi-user environment.

We, in our work, explore the utilization of standard off-the-shelf IEEE 802.11 compliant infrastructure and investigate efficient multi-hop routing in a vehicular scenario. Our approach does not require the development of any dedicated hardware, and the routing measures we propose can be used with any ad-hoc MAC protocol [6], [8] and [9]

B. The Optimized Link State Routing Protocol-

OLSR is a table driven and proactive protocol which involves regular exchange of topology information among the nodes in a network. It employs designated nodes called Multi Point Relays (MPRs) to facilitate controlled flooding of topology information. MPRs are also the sole constituent nodes in the route between any source-destination pair in the network. OLSR inherits the concept of forwarding and relaying from HIPERLAN. It is best suited for networks where the traffic is random and sporadic between several nodes rather than exclusively being between a small specific set of nodes in the network. Furthermore, the performance of the protocol as compared to a reactive protocol is even better if the source-destination pairs change with time. These scenarios where OSLR proves to be meritorious correspond to realistic ad-hoc network conditions wherein any node may want to initiate a communication session with the other in topology and termination of connections may also occur every now and then. In a vehicular scenario, for instance, communication may need to be initiated between any two vehicles for an interactive connection or for transfer of data of interest. Also critical updates like accident notification may need to be dispensed from any vehicle in the network [1], [2] and [4].

C. Multipoint Relays-

Each node in the network selects a set of nodes amongst its symmetrically-linked neighbors that help in controlled flooding of broadcast messages. This set of nodes is called the Multipoint Relay set of the node. The neighbors of the node which are not in its MPR set receive and process broadcast messages from the node, but do not retransmit them. The MPR set is selected such that it covers all the nodes that are two hops away. The smaller its size, the more controlled is the flooding [6].

D. Packet Scheduling-

Several emerging wireless technologies today are envisioned to co-exist synergistically for enabling

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ubiquitous and broadband wireless access. The heterogeneity in the merits offered by these technologies makes it attractive to investigate their integration for the design of fixed and mobile wireless systems. The challenge lies in the efficient utilization of wireless access interfaces at the disposal of a multi-interface system.

Multi-radio devices have emerged in the wireless market today. However, these usually incorporate independently functioning radios, and provide wireless access via a single interface at a time. In the event of user migration to an area where the coverage provided by an interface is lost, wireless connectivity for the device is switched to another interface which is in its zone of coverage. In regions when multiple interfaces are simultaneously capable of communication, the user is provided access via the higher data rate interface. This access methodology clearly does not leverage efficiently the presence of multiple wireless interfaces. The integrated operation of multi-radio devices has been investigated from an implementation viewpoint [5], [7] and [11].

Internet access in moving trains constitutes another challenging scenario for multi-interface wireless access. As the bandwidth required for serving several users in the train is high, wireless connectivity via multiple radio access networks needs to be provisioned. The internal train scenario comprises of users having Internet access via Bluetooth and IEEE 802.11a/b based devices. The user devices communicate with access points at the input of a train gateway. The gateway has multiple output wireless interfaces that provide connectivity to base stations and access points belonging to different radio networks. The Internet data from the users are aggregated at the gateway and the data packets are transmitted on the output interfaces. The base stations and access points receive these packets and send them to a network-side proxy that routes them to their respective destinations in the Internet. The proxy also collects the data generated by hosts in Internet for the users in the train. It schedules this data to be transmitted to the train gateway via the base stations and access points having wireless connectivity with the train. The gateway has an inbuilt functionality to act as user-side proxy to deliver to the users in the train, the incoming Internet data. The challenge lies in the efficient scheduling of packets for uplink transmission on different interfaces of train gateway and for downlink transmission from different base stations or access points to the gateway. Since bandwidth at high mobility is scare, appropriate scheduling measures need to be employed for efficient bandwidth aggregation across the wireless interfaces. Scheduling disciplines for multi-interface wireless systems are confronted with a challenge as the interfaces experience variation in channel conditions due to co-channel interference, path loss, shadowing and multi-path fading effects. However, the awareness of channel conditions of the interfaces can be utilized to enhance system performance [1], [3] and [10].

III. PROPOSED TECHNIQUE

In this paper, we propose a link-quality assessment methodology for enhanced adaptability of ad-hoc routing in a dynamically changing topology. The approach is based on the interaction of the networking layer with the underlying physical and link layers. We delineate the operational framework of a proactive topology adaptive ad-hoc routing protocol in a vehicular scenario, and demonstrate the effectiveness of the proposed routing enhancements in an IEEE 802.11b.

Ad-hoc networking has been a focus of active research for several decades. Several related aspects including routing, security and power control have been investigated. Conventionally the notion of ad-hoc networking has been associated with communication on combat fields and sites of disaster. However, with the emergence and economy of wireless technologies like IEEE 802.11, applications of ad-hoc networks have come to include office and home networking, self-organizing multi-hop wireless meshes, sensor networks, and inter-vehicle communication. We proceed to motivate the need for topology adaptive routing in a mobile scenario.

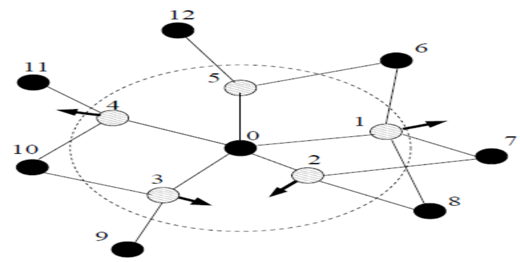

Figure 2: Routing dynamics in OLSR.

In our discussion we will consider connectivity between nodes as averaged over multipath and shadowing effects. The fast time scale of variation of connectivity due to these effects may render attempts towards adaptive routing infeasible. Moreover, measures like link-adaptation, equalization, and power control can be employed to mitigate affects of multipath and shadowing. The average node connectivity is thus impacted by path loss which depends on the distance of separation between two nodes. Consider the scenario highlighted in Figure. We assume a CSMA/CA medium access among the nodes in the topology. The nodes exchange periodic HELLO messages. All the nodes from which a given node successfully receives these messages are ascertained as the neighbors of the node. When the Signal to Noise Ratio (SNR) of a neighbor to a node becomes sufficiently low, the node is unable to receive HELLO messages and thus no longer regards the other node as its neighbor.

We first discuss the MRP selection process. Nodes 1-5 in Figure 2 represent the one hop neighbors of node-0, the reachability of which is assumed to be the dotted circle in the figure. The neighbor table of node-0 will have entries for each of its neighbor, and each such entry will include a list of 2 hop neighbors that the neighbor provides reachability to. As the MPR selection highlighted and executed on the neighbor entries 1 through 5, nodes 1, 3, 4 and 5 will be selected as MPRs. We note that node-1 will be preferred over node-2 as MPR because it offers connectivity to 3 two-hop neighbors while node-1 offers connectivity to only 2 two-hop neighbors. However, as shown in Figure 2, node-1 may be on verge of a breach of connectivity with node-0. Hence its selection as MPR is not an advisable choice. We reiterate that MPRs form intermediate nodes for routes to destinations and also do flooding of topology information. Hence loss of connectivity to an MPR can severely undermine network connectivity. In Figure 1 nodes-2, 3, 4 and 5 would constitute a better MPR set, with the mobility of node-2 as indicated in the figure 1. Similarly lack of

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mobility awareness in routing table calculation can adversely affect the network connectivity. For instance, during routing table evaluation at node-0, it is possible that the shortest path algorithm selects node-4 as the next hop to destination node-10. However, node-4 may be on verge of a breach of connectivity as shown in the figure. Hence, it would be better to select node-3 as the next hop for providing connectivity to destination node-10. The absence of mobility awareness in OLSR can also lead to inefficient routing and routing table instability. For instance, a neighbor may be on the verge of breach of connectivity due to reasons like increasing separation, a fading channel, etc. If the reach ability to such a neighbor is broadcast throughout the network, MPRs and routes will be evaluated based on this information. This can lead to data loss due to packet drops along the disconnected link. Again, the connectivity of a node to a neighbor may be oscillating. Consequently, the HELLO messages from this neighbor may only sporadically reach the node at which neighbor table is being maintained.

Each neighbor entry has a timer associated with it. On expiration of this timer, the entry is purged, and the MPR selection and route evaluation is performed. On rediscovery of the neighbor, an entry is added to the neighbor table, and the topology and routing table calculation is repeated. The updated neighbor and topology information is then broadcast via HELLO and TC messages. The nodes receiving new information via these messages re-evaluate their topology and routing tables, and relay any changes in topology. Hence if a neighbor oscillates in connectivity, the broadcast of its reach ability causes routing table oscillations in the network. This can lead to a loss of the data packet being routed through transient routes.

A. *MPR Selection Algorithm-*

In OLSR operation under a dynamically changing topology, a node selected as an MPR may move out of the MPR selector, thereby rendering a number of routes stale. In the transient period when route rectification is being done, packets will be lost for the data being routed. Therefore, it is desirable to come up with a metric for MPR selection at node x that not only considers the two-hop connectivity of candidate nodes in N(x), but also gives preference to their affinity with x. An affinity based algorithm that targets to alleviate the drawbacks of the MPR selection process in OLSR is proposed herewith.

```
output:  MPR returned by mpr_candidate
max  ← 0;
for n □ N(x) do
if n.affinity is high then
if n.neighbor2nocov >= COVthresh then
mpr_candidate  ← n;
break;
else
if n . neighbor2nocov. Haffinity > max then
max  ← n.neighbor2nocov × Haffinity;
mpr_candidate  ← n;
end
end
else
if n . neighbor2nocov. n.affinity > max then
max  ← n.neighbor2nocov × n.affinity;
mpr_candidate  ← n;
end
end
end
```

Algorithm: MPR Selection Algorithm with affinity enhancements

The selection algorithm starts with an empty set MPR(x), and then iterates over the following procedure. If there exist some nodes in N2(x) that are not provided connectivity by MPR(x), then for each neighbor n in N(x), the number of nodes in N2(x) which are not yet covered by MPR(x) but are reachable through this one-hop neighbor is evaluated. This number is designated as n.neighbor2nocov. The procedure highlighted via Algorithm is then executed. The MPR selection process is repeated until the MPR(x) set is able to fully provide connectivity to all nodes in N2(x).

In Algorithm all the nodes n in N(x) are scanned for eligibility as an MPR. If a node n is encountered which has a high affinity to x and has a neighbor2nocov value greater than a threshold COV thresh, then it is immediately selected as an MPR. This gives preferential treatment for MPR selection to nodes which are moving closer to x and have connectivity to COV thresh or more number of two-hop neighbors. COV thresh can be empirically decided based on the network density. For instance it can be evaluated as the ratio of the number of two-hop and one-hop neighbors. It then represents the number of two-hop neighbors of a node that on an average need to be provided connectivity via a one-hop neighbor.

B. *Packet Scheduling Policies-*

The policies for packet scheduling in a multi-interface wireless system. We first consider a scheduling scheme which does not require the awareness of wireless channel conditions of the interfaces. The scheduling policy selects the maximum bandwidth link that is free and schedules for transmission a head of line packet from the input queue on to it. For instance, consider a scenario with an IEEE 802.11a and a UMTS interface. At all times, the scheduling policy under discussion will choose the 802.11a interface if it is not busy and will choose the UMTS interface otherwise. This is because the IEEE 802.11a data rates are higher than what UMTS can provide. We name this scheduling policy Maximum Bandwidth Free Interface (MBFI), thus describing the mode of selection of interfaces for packet transmission. We note that the term bandwidth is not defined in an instantaneous sense, but corresponds to the benchmark data rate that an interface has to offer. For a scenario with perfectly reliable links and a saturated input queue, MBFI will guarantee the maximum scheduler throughput. Moreover, since the policy does not require any channel state information, it is easy to implement it in a multi-interface wireless system. We next consider a policy that makes scheduling decisions based on the awareness of channel conditions of the interfaces. At any time, this policy selects the interface with the maximum projected data rate for current packet transmission. We next describe its operation in detail. Let the system have N wireless interfaces. At the time of input packet scheduling, let K of them be free. Without loss of generality these can be numbered 1 to K. the packet scheduling policies presented.

We adopt a Markovian modeling approach and in order to keep the complexity tractable, make simplifying assumptions about the wireless interface characteristics [1] and [11]. The channel state of each of the interfaces is represented by a two-state Markov Chain model. The good channel state implies that a packet scheduled for this interface will be successfully transmitted at the constant data rate associated with the interface. The bad state, on the other hand, causes a scheduled transmission on an interface to be

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unsuccessful with the interface remaining busy for the duration of transmission. We assume the packet arrival process at the input queue to be Poisson, and the interface transmission time to be exponentially distributed with rate equal to the data rate of the interface. In an actual scenario, however, packet transmission times are not exponentially distributed. For a given transmission rate, a packet is transmitted in a constant time.

IV. RESULTS

Through experimental test-runs we showed that SBRS-OLSR adapts better to mobility and yields a higher UDP throughput than OLSR in the deployed vehicular test-bed. The link-layer awareness enables SBRS-OLSR to be responsive to variations in network connectivity and take proactive actions in choosing stable and durable routes.

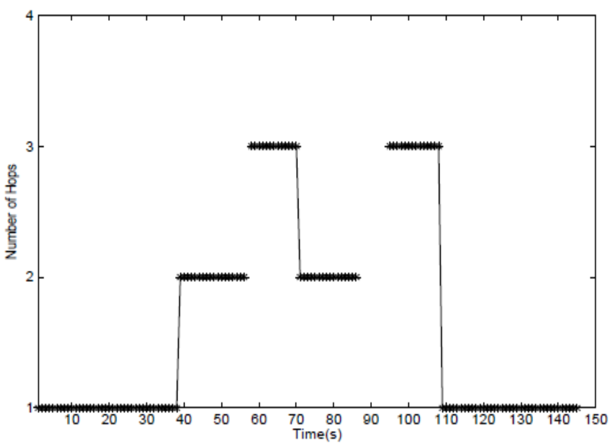

Figure 3: Number of hops for the route from receiver to sender for OLSR.

For the OLSR test run at 5 miles per hour receiver speed, the route from the receiver to the sender switches to 2 hops no earlier that t=38s, and no preemptive action is taken to render the sender node unusable (as in SBRS-OLSR) the SNR to which is falling. Eventually the sender moves out of range of the receiver node, and the new route is calculated (at t=38s) when the neighbor table entry corresponding to the sender times out. During the course of route evaluation by OSLR, the switching of the route from one relay to the other relay as the next hop occurs only upon loss of connectivity or expiration of timers of topology, neighbor or routing tables. Also, no preference is given to a better route when multiple routes with the same hop length can be evaluated from topology information. For instance during the interval 71-93s, relay-1 remains as the next hop for the route from receiver to sender. No criterion (like affinity) is employed by OLSR to ascertain that the route through relay-2 may be a better one. Only when connectivity to relay-1 is lost does the route switch to the one with relay-2 as the next hop. On the other hand, switches to better routes are more pronounced with SBRS-OLSR.

The routing performance is not dependent on the location of the nodes in the network; we change the deployment position of the UDP sender node and the relays. The receiver now spans a wider area of the parking lot and has a longer trajectory. However, the relative orientation of the nodes and the receiver position at the beginning of the test run remain similar. The test-run is performed as per the methodology indicated in the previous subsection, and at a receiver speed of 15 miles per hour. We suggest that SBRS-OLSR be further investigated for being considered a standard routing protocol for IEEE 802.11 based vehicular networks.

Also we demonstrated that a channel aware packet scheduling can achieve reduction in input buffer lengths and packet delays for different bandwidths and error rates of the wireless interfaces. We further showed that channel awareness enables a packet scheduling algorithm to prevent transmission when the channel conditions are anticipated to be adverse, thereby achieving a significant reduction in interference as well as battery power consumption.

V. CONCLUSION

Wireless access technologies are fast evolving to provide ubiquitous connectivity and support for high data-rate applications. The variation in wireless channel quality presents a challenge to their efficient design and operation. Functional isolation of networking layers can lead to reduced performance in wireless scenarios, as evident from well known issues like TCP throughput degradation. The adaptability of wireless networking stack to radio conditions, on the other hand, entails operational efficiency and enhanced system performance. We, in our work, highlight this fact by addressing some key aspects in wireless networking. As most of the Internet data today is carried by TCP, the integration of the mobile devices with the wired world mandates its use as a transport layer protocol. We address the performance degradation of TCP in wireless scenario by introducing an optimization framework based on the congestion control dynamics of a bulk-transfer TCP flow. We observe patterns called cycles in the dynamics and develop an optimization strategy that enables utilization of adaptive link-layer measures to enhance TCP throughput. We discuss the essence behind the optimization approach, which is to protect selective rounds of TCP by ensuring a high segment success probability. The high success probability can be obtained via link layer measures like robust modulation and coding, greater transmission power, etc. We demonstrate the intuition behind our optimization methodology by first presenting TCP throughput enhancement via adaptive power control in a simplified scenario.

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