Providing Service Continuity in Ad Hoc Networks

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Abstract: Most of the investigations on ad hoc protocols do not consider the fact that future wireless networks are capable to adapt their behaviour to the channel situation. These adapting functionalities haven't been developed to be used in multihop ad hoc networks. Therefore the performance of ad hoc routing using IEEE 802.11a turned out to be unexpected inefficient. This paper presents a new concept to improve ad hoc routing protocols exploiting IEEE 802.11a link adaptation capabilities. The IEEE 802.11a link adaptation information is used to predict the link stability and link lifetime. Prediction is very useful to ensure continuously data delivery, since routes can be adapted to the network situations.

1 Introduction

Nowadays the trend is towards the wireless world, providing public access to the Internet via wireless devices at high data rates. Wireless Local Area Networks (WLAN) like IEEE 802.11a work at 5 GHz, supporting transmission rates up to 54 Mbit/s. High data rate and limited transmission range makes WLAN systems reasonable for areas with a high population density and users with the need for high data rates. Due to the limited transmission range the needed density of Access Point/Router (AP/AR) has to be very high. This could be reduced by either increasing the transmit power or enabling intermediate terminals to forward the data to users outside the access point range.

1.1 State of the Art

The solution is to expand the fixed infrastructure using multihop connections. To handle the mobility and fast topology changing on the network, ad hoc routing protocols have been developed. Routing protocols are divided in two groups, the proactive and reactive protocols. Proactive approaches have a route when requested, therefore minimizing the packet delay. Reactive protocols avoid to maintain unneeded routes, but to the cost of a higher route discovery and packet delay. All current routing protocols have been developed using legacy IEEE 802.11. The next evolution step is IEEE 802.11a working at 5 GHz. The main extensions during the evolutions steps are the implementation of more than one transmission mode ”PhyMode”. However, no routing protocol considers the impact of these PhyModes. The PhyMode adaptation has not been standardized by the IEEE group, but its impact on the IP Layer and especially to the ad hoc routing turned out to be immense. Our proposal is to react before a link breaks. Based on link adaptation information the link state is predicted. The route will be rearranged before the link breaks. We present a new route rearrangement protocol based on the prediction, the Early Route ReArrangement (ERRA). ERRA prevents unnecessary signalling, avoids packet loss and minimizes packet delay. Therefore, our approach uses the ad hoc network capacity more efficiently than existing protocols. We structured the paper as follows: First we start with a brief overview about the IEEE 802.11 link adaptation. In section 3 the prediction fundamentals are explained. Finally, the ERRA signalling is presented to use the link prediction effectively and the last section presents simulation results and concludes our paper.

2 IEEE 802.11a Link Adaptation

The IEEE 802.11a Medium Access Control (MAC) layer is mainly the same as the MAC layer of 802.11b and the legacy 802.11. The main difference to 802.11a are the transmission modes [Ie99]. 802.11a can chose between eight coding schemes, so called *"PhyModes"*. Since IEEE 802.11 does not define any rules for an internal link adaptation (LA), each vendor implements a proprietary LA. Independently from the flavour of the LA, all algorithms are based on the similar principle, that is, with degrading channel conditions a lower but stronger PhyMode is chosen (or a higher but weaker one, when the conditions improve). To evaluate the performance of the IEEE 802.11a MAC, our simulation tool has been extended with a fast and efficient LA. The developed LA could be seen as an enhanced version of the Auto Rate Fallback (ARF) [KM97] protocol; the implemented version addresses the following design principles: Fast reaction on condition changes is one of the major requirements for an LA, while slow changes must be considered as well. To fulfil these requirements, our LA contains three different buffers of size 5, 10 and 25 to store the PhyModes used in the past, along with the information whether the packet has been acknowledged or not. When the error ratio associated to a buffer is exceeded, the PhyMode is decreased immediately. The LA starts in an initial state until all buffers are filled. In this state, the LA converges fast from the initial PhyMode to the current link conditions. It is particularly important to reach an applicable PhyMode before the IEEE 802.11 protocol starts discarding packets. Therefore, a medium coding scheme is chosen for the initial PhyMode. Once all buffers are filled, the LA switches to the steady state where all buffers are considered. The LA uses a weighting vector to combine the different error rates. The resulting error ratio is used to decide whether the PhyModes has to be increased, decreased or left unchanged. When the link to a certain neighbour is idle for a given period of time, all buffers of the

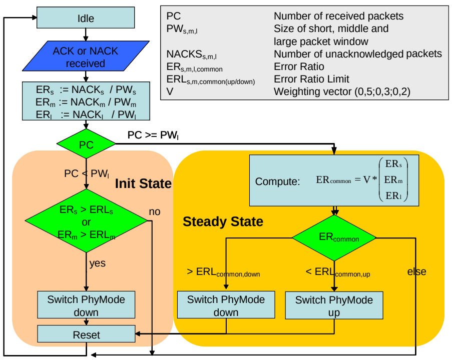

Figure 1: Link Adaptation

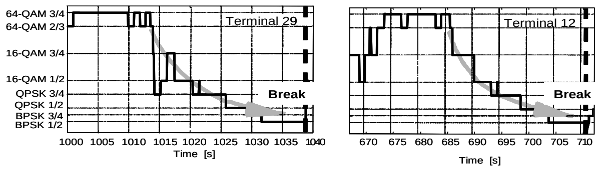

Figure 2: Example for the Link adaptation behaviour

according LA instance are deleted to avoid stale information. Consequently, whenever a node wants to communic-ate with another node and it is either the first time or the link has been idle for a certain time the initial PhyMode must be used at the beginning. Figure 2 shows the adapted Phy-Modes from one of the source nodes: Due to the mobility the next hops are changing. On the left hand side, terminal 29 was the next hop, on the right hand side it was terminal 12. The typical behaviour ("downstair-pattern") prior to a link break (thick dashed line) can be observed.

3 Prediction based on the Link Adaptation

The two subplots in Figure 2 illustrate that the link quality degrades when the node departs from its communication partner. The LA adapts whenever necessary the PhyMode to avoid interrupting the connection. Due to this behaviour we are able to predict the link interruption. Continuous degradation of the PhyMode is a hint for the network layer that the link may break soon. This information triggers the routing to change and to adapt the route according to the actual situation. Being able to predict a link interruption has large benefits. The usual routing protocols only react after the link is broken, while, when exploiting LA information, they can act before the breakage occurs. The next step is to evaluate the relation between this "downstair-pattern" and a route interruption. Therefore we define a weighting vector that weights the importance of each PhyMode step related to the breakage (cf.). Changing from BPSK ¾ to BPSK ½ (weight 7) is more important for the breakage prediction as switching from 64 QAM 2/3 to 16 QAM ¾ (weight 2). When the LA has to use the strongest PhyMode (BPSK ½), it checks the steps in the past for the "downstair-pattern". The LA adds up all switching steps for a certain time interval, when the sum exceeds a limit. The link is considered suspicious and might break. This information triggers the routing layer to update the route [WFX04].

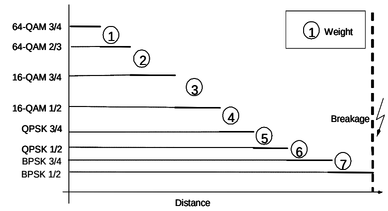

Figure 3: Weighting Steps

3.1 Early Route Rearrangement and Early Route Update

In the previous section we presented how to forecast the degradation of a link. This section describes an approach that profits from early triggering. The Early Route ReArrangement (ERRA) is derived from the local repair idea, which is part of the Ad Hoc On Demand Distance Vector (AODV) routing [PBD03] protocol. ERRA does not wait until the link is broken; prior to a breakage, ERRA rearranges the route to avoid disruption. In Figure 4 a signalling example is given. The initial route starts from source node 2 to destination node 7. One intermediate node (5) is going to leave the connection This can be detected by node 4; since it has to adapt the PhyMode to node 5. Accordingly, node 4 triggers the ERRA procedure to rearrange the route, when the Phy-Mode. BPSK ½ must be used. Node 4 locally broadcasts[1] a rearrangement request (ERR_REQ) with a pre-determined PhyMode that is higher than the last one used for the connection. In Figure 4 the request is sent with QPSK ½, thus node 5 does not receive the request directly. Node 8 forwards the request to node 6 which is aware of a route to the destination. Node 6 respondes (ERRA_REP) and provides an alternative route. Node 4 compares the hop count between old and new route. If the new hop count is smaller or equal, the route is used immediately. Otherwise node 4 uses the new route as soon as the old connection is broken. Further details can be found in [WFX04]. ERRA is going to rearrange the route to provide uninterruptible connections, since route continuity is a important requirement for transport protocols. However, ERRA is wasting one feature in the presented situation. In the moment a notification for a degrading route is received, the connection still exists and can be used for the route update process. Therefore we have extended ERRA and developed the Early Route Update (ERU) protocol details could be found in [WFX04].

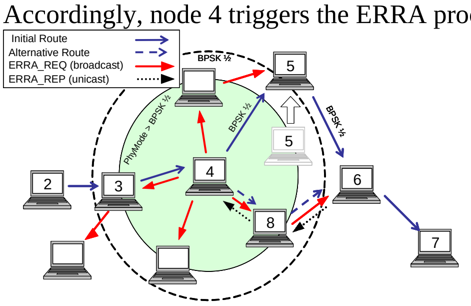

Figure 4: ERRA Signalling

4 Simulation Results and Conclusions

We simulated several scenarios, investigating the LA and the cross-layer interaction between LA and IP routing. The scenario consists of a square area (100m x 100m) with 40 nodes moving according the RWP [BHP03] mobility model. Three routes are loaded with constant-bit-rate traffic; the amount of traffic is in-creased per simulation. The packet size is 512 bytes, RTS/CTS is use to avoid the hidden node problem. Figure 5 presents on the left hand side the average throughput percentage over all three routes, the ERRA and ERU approach are compared with the AODV local repair mechanism. It can be seen that under high load conditions the network gets congested and can not provide a sufficient throughput. More important, no throughput degradation can be seen with the ERRA or ERU strategies. It must be

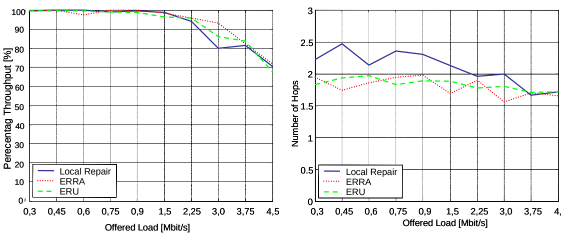

Figure 5: Throughput [%] and Average Hop Count

[1] The time to life (TTL) for the broadcast is calculated according the AODV local repair rules [PBD03]

mentioned that both approaches affect only a small fraction of packets. On the right hand side the average Hop Counts versus offered traffic is shown. Under low traffic conditions ERRA and ERU shorten the route. When the offered traffic increases, ERRA and ERU reveal the same performance as local repair. They do not negatively influence the throughput, but shorten the routes. More important than throughput or hop count is the packet delay. By avoiding route breaks the packet delay is decreased. Figure 6 shows four complementary cumulative distribution functions (CDF), each representing the delay distribution under different traffic conditions. It can be seen that both approaches outperform the local repair. Under low load conditions ERU shows the lowest delay.

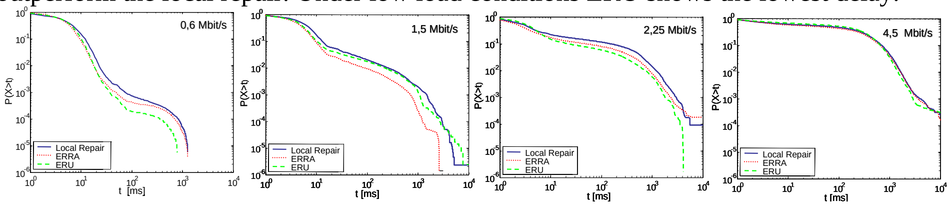

Figure 6: Delay under different load situations

With an increasing amount of traffic both still show smaller delay than local repair. This is a proof, in our opinion, that link prediction improves the route continuity and is used to avoid packet losses, and decreases packet delay because a new route discovery is avoided. This work shows existing potential for protocols working across ISO/OSI layers. Similar information from layers below can be used to control handover, routes, PhyModes, etc. Also the other way around, lower layer can profit from higher layer knowledge, like connection duration, QoS requirements.

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