Improving Prediction in the Routing Layer of Wireless Networks Through Social Behaviour

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Abstract. Community networking, together with the Bottom-up-Broadband initiative, is an emerging model for the Future Internet across Europe and beyond where communities of citizens build, operate and own open IP-based networks, a key infrastructure for individual and collective digital participation. As any other network that mixes wired and wireless links, the routing protocol must face several challenges that arise from the unreliable nature of the wireless medium, the self-management by the users, and the organic growth. Our research focus on improving the performance of routing protocols in wireless networks. The first research topic is about predicting both the link quality and the path quality in wireless community networks. In the second research topic, we analyse the prediction opportunities of the control packets in the routing layer of the OLSR protocol (in Mobile Ad-hoc Networks, MANETs). This paper contains the main results we have obtained in both topics. We also explain our current research on the "social behaviour" of people who carry with them the devices that form the nodes of wireless networks (e.g. smartphones) in real scenarios.

Keywords: Routing Protocols, Wireless Networks, Network Topology Prediction, Link & Path Quality Prediction, Social Behaviour, Community Networks, MANETs.

1 Link Quality Prediction

Link quality (LQ) tracking helps the routing layer to select links that provide the best features for communication. Moreover, LQ prediction has proved to be a technique that surpasses LQ tracking by foreseeing which links are more likely to change its quality. In [3] we focus on LQ prediction by means of a time series analysis. We apply it in the routing layer of large-scale, distributed and decentralized networks. We demonstrate that this type of prediction achieves a success probability of about 98% in both the short and long term.

In [2] we enhanced and extended the previous work by giving more detailed discussion of the previously presented global studies and including a new one that relates topological features of a link with the behaviour of its

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link quality. We included two new subjects. The first analyses the variability of LQ prediction (1) between links and (2) over time. A second new subject proposes and discusses an enhancement to the prediction process that benefits from the global and individual behaviour of link qualities observed.

Those studies demonstrate that time series analysis is a promising approach to accurately predict LQ values in community networks. This technique can be used to improve the performance of the routing protocol by providing information to make appropriate and timely decisions.

As future work, we plan to identify which links contribute most to the error in the LQ prediction and to understand what factors make it more difficult to predict the behaviour of these links. We also want to analyse if there is a subset of links that provides real trends in LQ. Moreover, we plan to improve the prediction process discarding those links whose relation between LQ and prediction accuracy is above a certain threshold. Furthermore, we are currently implementing our proposal, that will allow us to determine its cost, how to be used by routing protocols, and if the addition of other sources of information (e.g. NIC parameters) could improve the predictions. Finally, we want to extend our analysis to other community networks, to evaluate if the observed behaviour could be generalized.

2 Path Quality Prediction

End-to-End or Path Quality (PQ) tracking helps the routing layer to select paths that provide the best features for communication. We believe that PQ prediction surpasses PQ tracking by foreseeing which paths are more likely to change its quality. In [1] we focus on PQ prediction by means of time-series analysis. We apply this prediction technique in the routing layer of community networks. We demonstrate that it is possible to accurately predict PQ with an average Mean Absolute Error of just 2.4%. Particularly, we analyze the path properties and path ETX[1] behavior to identify the best prediction algorithm. Moreover, we analyze the PQ prediction accuracy some steps ahead in the future and also its dependency of the time of the day.

We have presented results from 4 well known learning algorithms that model time series. All of them achieved high percentages of success, with average Mean Absolute Error values per link between 2.4% and 5% when predicting the next value of the PQ. We also analyzed the error variability and found that three of them presented similar performance, whereas the fourth performs worse due to outliers with larger errors. A more detailed study of the best prediction shows an average absolute error less than 1. We have also observed differences in the prediction behavior during day and during night, as it happens with actual ETX values.

[1] ETX is the number of expected transmissions of a packet necessary for it to be received without error at its destination. ETX varies from number of HOPS (perfect) to infinity.

The future work in PQ is similar to LQ. We want to extend this analysis to other community networks. Moreover, we plan to identify which paths contribute most to the errors in the PQ prediction and to understand what factors make it more difficult to predict them. We also want to study the impact of errors in routing decisions, and to study a solution with two different predictors for day and night. Finally, we plan to improve the prediction process discarding those paths whose relation between PQ and prediction accuracy is above a certain threshold.

3 Control Information Prediction

Several social computing participation strategies use mobile ad hoc or opportunistic networks to support the users activities. The unreliability and dynamism of these communication links make routing protocols a key component to achieve efficient and reliable data communication in physical environments. Often these routing capabilities come at expenses of flooding the network with a huge amount of Topology Control Information (TCI), which can overload the communication links and dramatically increase the energy consumption of the participating devices. In previous works we have shown that predicting the network topology in these work scenarios helps reduce the number of control packets delivered through the network. This saves energy and increases the available bandwidth. In [4] we present a study that extends previous works, by identifying the impact of predicting the TCI generated by routing protocols in these networks. The prediction process is done following a history-based approach that uses information of the nodes past behavior. The paper also determines the predictability limits of this strategy, assuming that a TCI message can be correctly predicted if it appeared at least once in the past. The results show that the upper-bound limit of the history-based prediction approach is high, and that realistic prediction mechanisms can achieve significant ratios of accuracy.

The main contributions are: (1) we observed that around 80% of the times, for low densities of nodes, a packet has already appeared in the past. This percentage falls to 50% when considering a network with a higher node density. This demonstrates that the upper bound limits of our strategy remain high for an ample variety of interaction scenarios, which make us expecting important benefits for mobile collaborative applications that use these networks as communication support. (2) the results also show that few packets contribute significantly to the total percentage of packets delivered through the network. This means that there is a high opportunity for predicting the TCI, and this prediction can be just focused on a small subset of packets. (3) we have identified the role played by different history-depth patterns, prediction policies, confidence mechanisms, and the combination of several approaches.

As a future work, we plan to analyze in detail all combinations of work scenarios, considering node density, speed, and mobility patterns. We also want to develop more complex confidence mechanisms, and combine the prediction approaches to see if their benefits can be accumulated. Moreover, it would also be interesting to analyze the prediction performance in opportunistic networks involving heterogeneous environments (to address IoT-based solutions).

4 Improving Prediction Through Social Behaviour

Our previous research steps have demonstrated the importance of the prediction for both Link & Path Quality, and also for Control Information packets. In a real scenario, the nodes that compose the wireless network correspond to the communication devices carried by the people (e.g. smartphones). Our current research topic is to incorporate the social behaviour of people in the prediction process and to study if this new factor improves the obtained results. We want to asses if this "social behaviour" is real or just virtual. We focus our analysis in the mobility of people (e.g. a group of people in a museum guided visit) and in time factors (e.g. day and night, workdays and weekend).

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