Performance of Wireless Mesh Networks utilizing Beamforming Antennas

Sebastian Heglmeier
first supervisor: Prof. Dr. Jens-Peter Redlich
second supervisor: Prof. Dr. Alexander Reinefeld
in METRIK since: 2007-11-01

Problem statement

A network for earthquake early warning (EEWS) is envisioned to consist of hundreds of nodes. These are scattered throughout an endangered area, placed by both public authorities and private citizens. The network described serves two aims: at first, nodes must collectively trigger a network wide alarm instantaneously after the detection of an earthquake's primary wave. During this decision process, we must ensure that alarming messages coming from the nodes propagate fast through the network without being lost. Particularly in this critical situation, nodes signalling more or less simultaneously right after p-wave detection are likely to cause numerous collisions, what in turn impacts speed and reliability of the alarming routine. Beyond that, the second purpose of the EEWS is to act as a disaster management network directly after the first severe shakings. At that point in time, certain nodes having failed due to collapsing buildings thinned out the network, even network partitioning may occur. In order to remain fully functional, the network must stay well connected, so that bypassing taskforce teams may query the whole network from any location.

A technology to improve the so defined performance of an EEWS are *beamforming antennas* (BFAs). By dynamically focussing most of their signal's energy towards the intended receiver of a packet, they achieve a higher signal quality at the receivers antenna and up to twice the link range of common omnidirectional antennas. Additionally, beamforming antennas are less susceptible to interference from areas besides their direction of focus. Within our network, these properties could translate to a more reliable alarming period due to a higher signal gain, less interference generation towards unwanted directions and attenuation of interfering signals, as well as an increased connectivity among the nodes during the following period of queries and data dissemination (longer link ranges). Beamforming antennas are yet very expensive, furthermore their advantages regarding longer link ranges are exploited best when deployed elevated on top of buildings. Therefore we assume that within a concrete EEWS only a fraction of nodes will be equipped this way, while the remain of nodes still uses omnidirectional antennas, leading to the term *heterogeneous* WMN. Protocols for heterogeneous WMN are designed for special usecases regarding traffic pattern, percentage of BFAs, antenna types or network topology. The outcomes of recent research can not be directly mapped to our usecase, the behaviour of BFAs and the underlying protocols therefore not be predicted in our scenario.

Approach

The goal of the dissertation is to examine the advantages of BFAs in the chosen disaster scenario and enhance mechanisms on MAC and routing layer to further increase performance. Primarily, proper models have to be chosen where simplified models would lead to draw unrealistic conclusions, namely antenna-, channel- and network topology-models. Additionally, basic algorithms for directional MAC and routing (CADMAC, DDSR), a traffic pattern (alarming, querying) as well as performance metrics (latency, throughput) need to be chosen. The so defined setup is examined in the discrete wireless event simulator JIST/SWANS. These observations define an "area of scientific/economic interest", which calculates from the measured performance gains in dependency from the percentages of BFAs used. Numerous challenges arise after that point. The protocols at MAC and routing layer need to be adapted in a cross-layer manner to the scenario specific properties: circumvention of antenna deafness and hidden node problems combined with scheduling and capture aware route setup are the main factors which influence performance.

Current and Future work

Until end of the year, implementation of the fundamental concepts of beamforming on the physical, MAC and routing layer within the wireless network simulation environment will be finished. Afterwards, evaluation and analysis identify current potentials and deficiencies of basic heterogeneous routing- and MAC mechanisms within the area of interest. In the subsequent phase, the current protocols will be enhanced in an iterative development cycle in order to exploit and evaluate features of BFAs which are not consistently exploited so far, as nullsteering, directional longshots and multiple input multiple output (MIMO) properties.