The Berlin RoofNet Project

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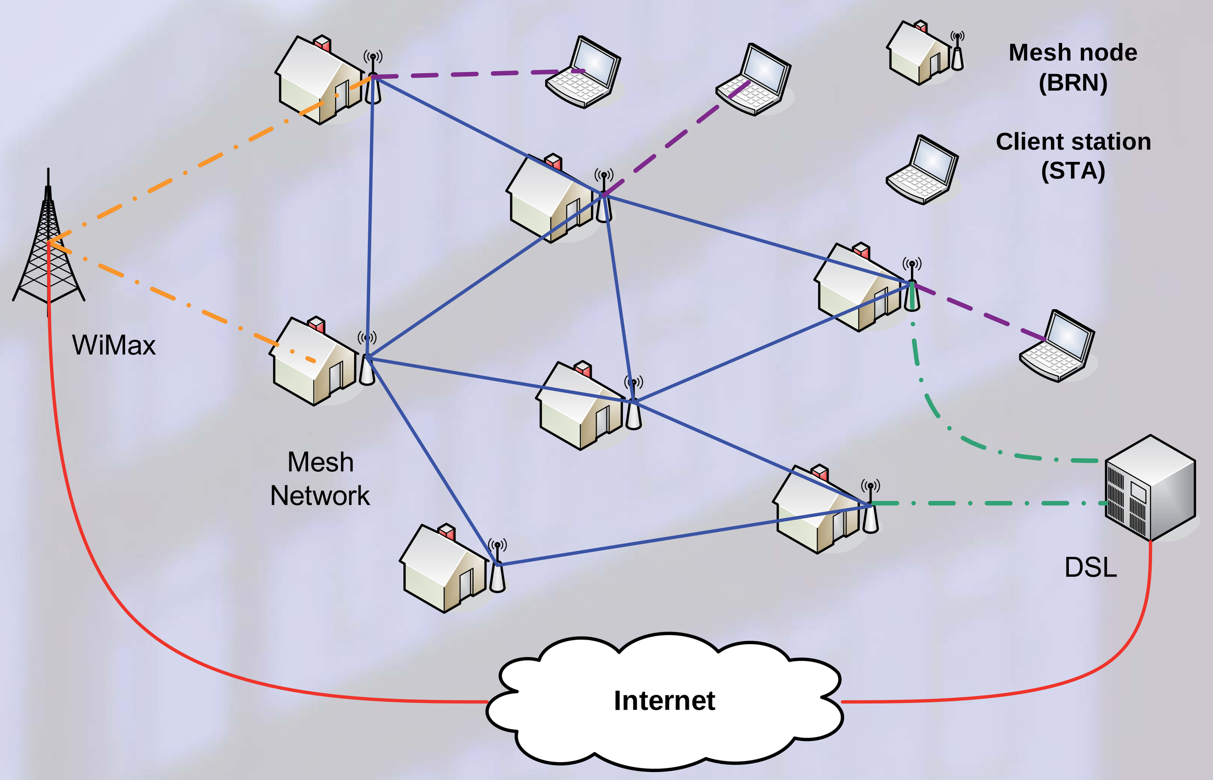
Introduction

Wireless multi-hop mesh networks play an increasingly important role as community networks that provide Internet access in urban areas. A wireless community mesh network consists of nodes (mesh nodes and associated clients) connected by wireless links. The nodes are free to organize themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably. Therefore self-organization is one of the key success factors.

Wireless Community Networks

In the scenario of a wireless community multi-hop mesh network the households are equipped with so-called mesh nodes, which form the mesh network.



Typically only a subset of mesh nodes is directly connected to the Internet. These gateway nodes share their Internet access with other nodes in order to provide Internet connectivity to all participants. Therefore mesh nodes forward packets to the Internet gateways in a multi-hop fashion. End users use off-the-shelf devices like notebooks and PDAs to interact with the network.

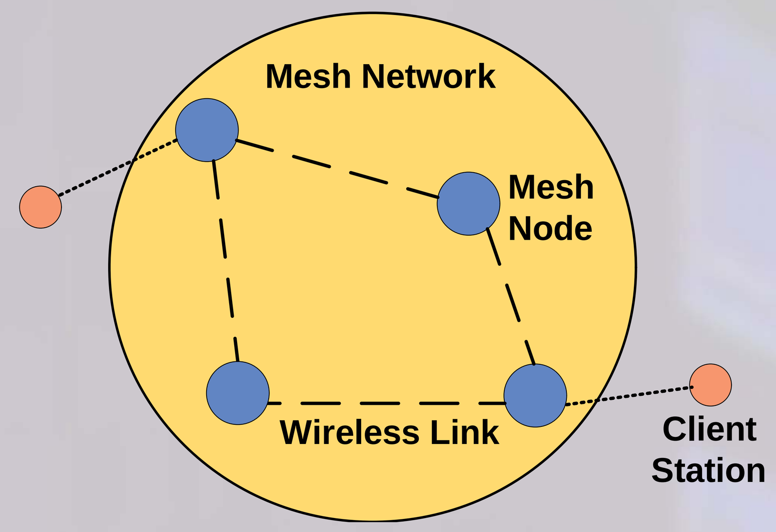
Self-Organization as Main Requirement

A community mesh network must be usable for inexperienced end users. In practice, the user should not care about the problem of IP address allocation, Internet gateway selection and software distribution. The goal is to offer an approach, where the client is doing no configuration except to connect to the network [2].

In order to achieve full self-organization, the following problems must be addressed. Nodes may spontaneously join or leave; the mesh network should be able to react to structural changes (unplanned growth). Resources needed for operation are not previously calculated and allocated. Furthermore, a central authority is not available, i.e. all services must run in a decentralized manner. This way the role of the operator changes from administration and maintenance to a provider for services like charging, billing, etc.

Architecture

The BRN [1] could be characterized as a wireless ad-hoc multi-hop mesh network. It has a 2-tier architecture: On the first tier there is the BRN core network consisting of BRN mesh nodes and there are client stations on the second tier. This approach leads to two types of links: links between mesh nodes use BRN protocol, whereas IEEE 802.11 is used for links between client stations and mesh nodes. The advantage of this approach is that client stations do not have to be modified.



The BRN uses a routing protocol based on Dynamic Source Routing (DSR) [3] enhanced with ETX [4] metric. It operates on layer 2 and is therefore layer-3 agnostic. From the client's point of view the BRN network looks like a huge virtual Ethernet switch, i.e. it relays Ethernet frames from client stations.

Software Distribution Platform

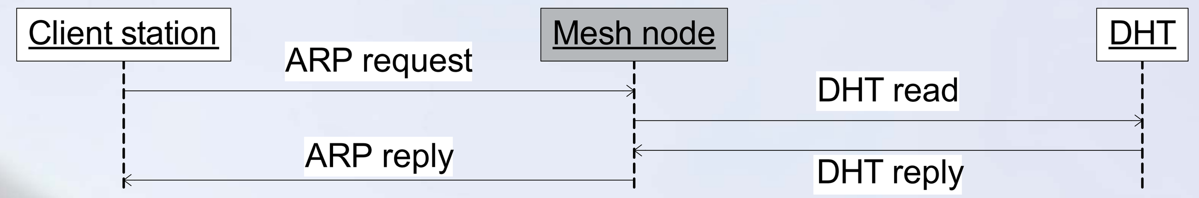
In the BRN the Software Distribution Platform (SDP) automatically updates all mesh nodes when new software becomes available. It does not rely on any other service, instead a simple and robust infection-like algorithm is used. Each node periodically announces its software version. An out-of-date neighbor requests the new software via Trivial File Transfer Protocol (TFTP).

Self-Organization through P2P

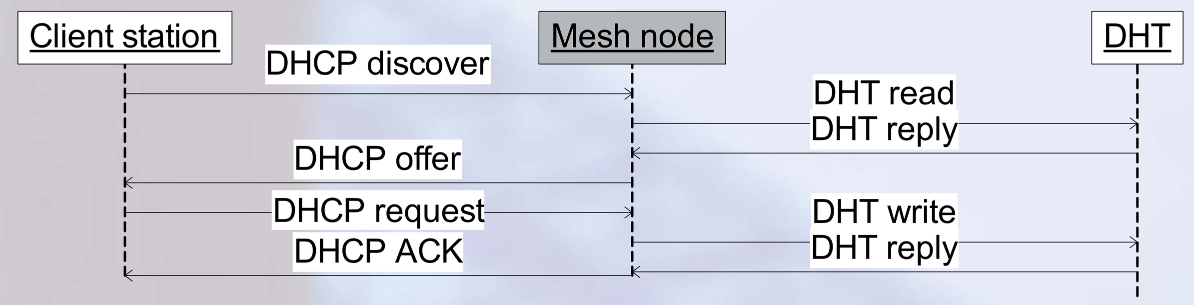
Peer-to-peer (P2P) systems are distributed systems without any centralized control. P2P systems offer advantages in scalability, robustness and availability. We based our solution on Chord [5], a distributed hash table (DHT) for file storage.

DHT-based Realization of DHCP, ARP and Gateway

If a client station wants to communicate with another station it creates an ARP request to resolve the other's MAC address. In BRN client stations do not communicate directly with each other. Instead they use mesh nodes, which intercept all ARP requests and resolve it using the DHT.



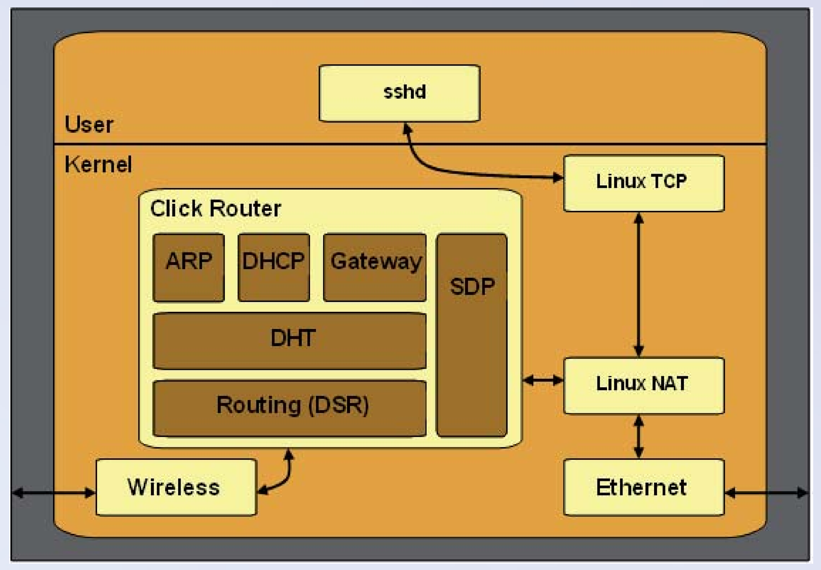
After a client station associates with one of the mesh nodes it tries to obtain an IP address using DHCP. The mesh nodes provide a distributed DHCP service, whereas the data is stored in the DHT.



Furthermore, Internet gateways along with its metrics are stored in the DHT using a well-known key. All incoming packets with destination IP addresses outside the BRN are routed to gateways: the mesh node queries the DHT for the gateway key resulting in a list of available gateways, from which the gateway with the best metrics is chosen.

Evaluation in our Testbed

For the evaluation in a real world environment we used our campus testbed. The tests demonstrated the practical feasibility of our approach and validated the simulation outcomes. As mesh nodes we are using Netgear's WGT634u router (MIPS/200MHz, 32MB RAM, Atheros IEEE 802.11b/g wifi card). The MIT's Click-API is used as the basis for our routing protocols and services.

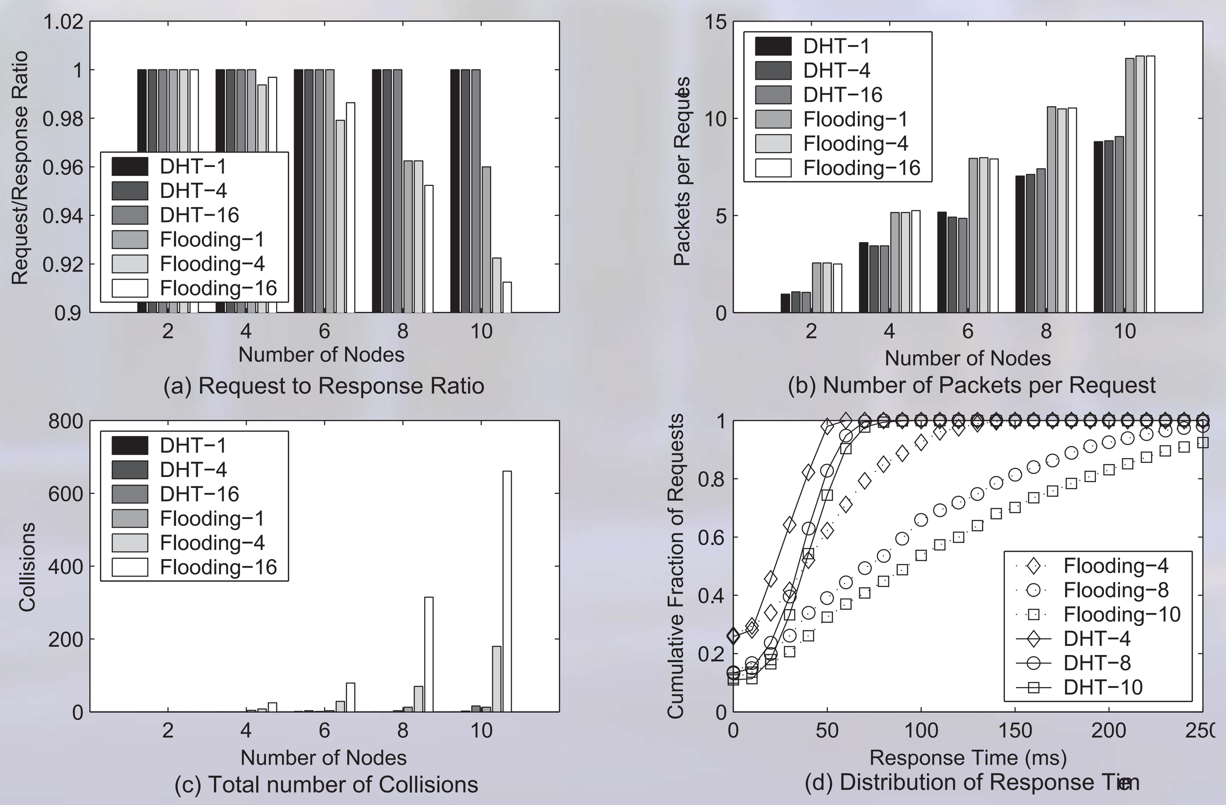


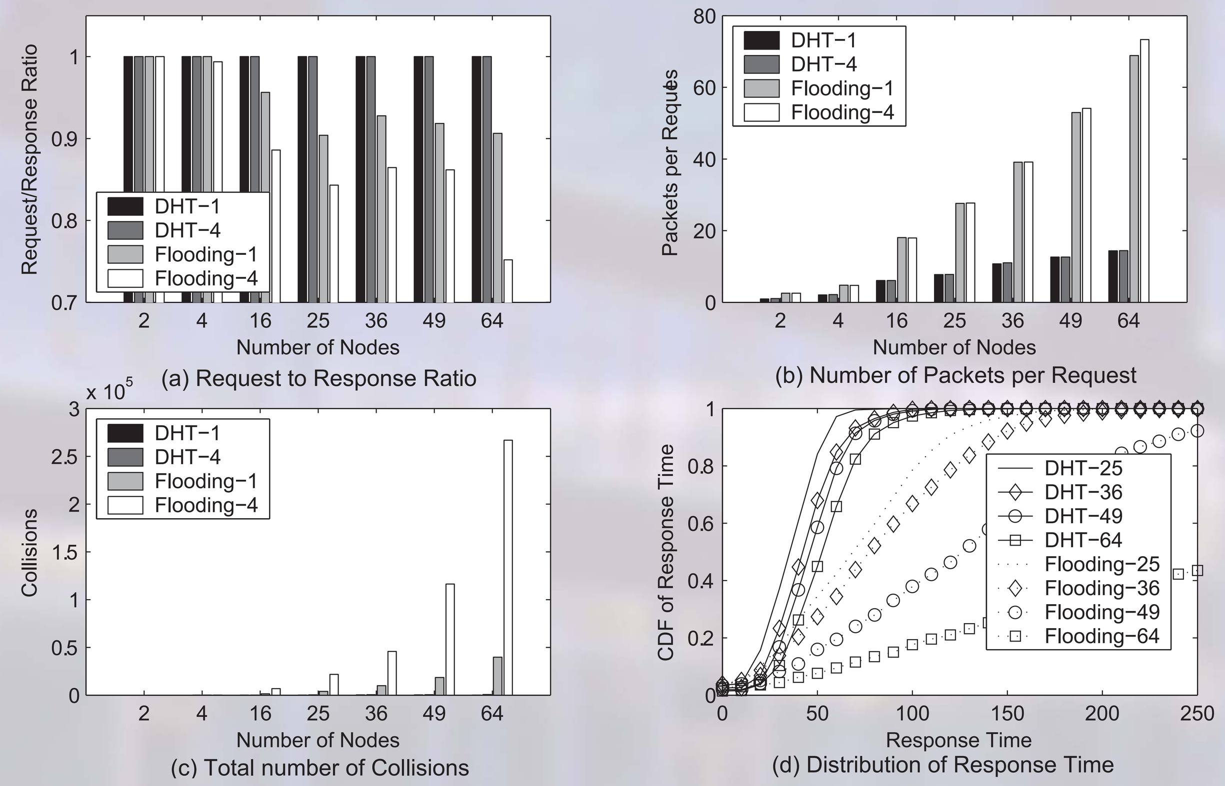
Services like ARP, DHCP, Gateway make use of the DHT which itself relies on routing. Only the software distribution system is independent from routing and DHT.

The BRN testbed consists of nearly 50 mostly indoor mesh nodes. It is used to validate results obtained from simulations in real world. Furthermore, the testbed is used by the students of the Humboldt University for internet access as well as for VoIP. Therefore a Virtual Private Network (VPN) solution especially for mesh networks was designed and implemented.

Simulation Results

We used the network simulator (ns2) together with the Click-API for ns2 (NSClick). We chose the two-ray ground radio propagation model. Furthermore, the medium access is coordinated using the DCF of IEEE 802.11. The bit-rate was set to 54Mbit/s. The simulation scenario consists of a number of mesh nodes, to which a number of client stations are connected to. Each client obtains an IP address via DHCP and periodically issues ARP requests.





The DHT-based approach outperforms traditional approaches like flooding on the string topology (left). It has a higher response ratio, needs fewer transmissions, responds faster and fewer packets collide. The simulation results using the grid topology (above) confirm our observations about the reliability and traffic load from the string scenario. Again, the DHT needs fewer transmissions, produces fewer collisions and is able to respond faster to an ARP request in relation to flooding.

Conclusions & Future Work

Services like DHCP, ARP, Internet gateway and SDP are necessary to achieve self-organization in wireless community mesh networks. We presented efficient realizations of these services using a DHT. Furthermore, with the help of simulations and an evaluation in the BRN testbed we showed that using a DHT to realize services like DHCP and ARP that otherwise had used inefficient algorithms like flooding make sense and lead to more reliable, efficient and responsive solutions. Our future work will concentrate on the realization of additional services like DNS as well as DHT improvements like the detection of node malfunctions and redundancy.

References

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