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Title: **Routing Protocols for Wireless Ad hoc ATM Networks**

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Routing Protocols for Wireless Ad hoc ATM Networks

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I. Introduction

Ad hoc wireless LANs are decentralized mobile networks and are designed with regard to spontaneous communication between portable nodes that can form a network autonomously without any need for access to fixed core network, e. g. [1, 2, 3, 4, 5].

In the full paper multihop networks are considered which apply wireless ATM transmission. Multihop networks are decentralized radio networks that allow connections between nodes without direct links. By that, the limited receive / transmit range is extended by routing data traffic from neighbour to neighbour, so that several intermediate nodes may be involved.

End-to-end virtual connections have to be established before data can be transmitted, since ATM transmission is considered in this approach. This requires a network protocol which supports network routing functions as well as procedures for connection set-up and release.

The main problem within a mobile ad hoc network is its dynamics. The topology is likely to change very frequently. When a mobile node joins an ad hoc network, i. e. becomes active, or moves within the network, this mobile node has to notify itself to its neighbours. In case the mobile node leaves the network, due to loss of coverage or de-activation, the network has to be aware that this node is not available anymore. These changes of network topology has to be considered when establishing a connection. The topology information stored in the databases of the network nodes may be updated each time the topology changes, or gathered only when needed.

These two different approaches of gathering of topology information can be categorized as *proactive* and *reactive*. A proactive technique scans the topology very frequently to obtain the most actual information for the routing algorithm. The reactive technique scans only if no information is available or is found to be invalid.

Selecting a suitable network routing mechanism is a trade-off between the amount of network capacity required for topology updates and capacity required for topology information gathering during connection set-up. Especially for ad hoc systems, the routing mechanism has to be robust against sudden changes in network topology, resulting from the wireless nature of the entire system.

II. Routing Platforms

Several routing platforms exit which are already in use or proposed for implementation. Most networks perform routing by the use of a routing directory or table.

In the full paper existing routing platforms will be investigated for the use in multihop ad hoc WATM LANs with regard to database organisation and the gathering of topology information.

The routing platforms analysed are

1. PNNI (*Private Network Network Interface*) Routing for the B-ISDN – a concept of the ATM Forum for use with private ATM-Switches and groups of Switches [6],
2. IP (*Internet Protocol*) Routing – today's de-facto standard for the Internet sublayer [7],
3. ZRP (*Zone Routing Protocol*) – an add-on protocol stack discussed by the IETF (*Internet Engineering Task Force*) for wireless IP based ad hoc LAN [8].

A. PNNI-Routing

PNNI uses a specially designed *Routing Hierarchy* to summarize clusters of nodes into *Peer Groups* (PG). These *Peer Groups* are organized recursively so that a hierarchical topology is built up of the whole network (see Figure 1). The lowest level consists of the physical topology of the network. A Peer Group is represented to the higher layer by an elected *Peer Group Leader* (PGL) which are connected by *logical* links. A separate topology database containing information on its Peer Group and the rest of the network area is administrated at each node. The *Peer Group Leader* is responsible for providing the higher layer with information on his *Peer Group*, so that this information can be announced through the rest of the entire network. In the upper level a *Peer Group* is represented by a *Logical Group Node*.

PNNI repeats this process up to the highest layer which represents the entire network.

PNNI-Routing-Protocol PNNI is a decentrally organized routing platform, where each node has an abstract knowledge about the topology of the entire system. Hence, each node is able to compute a route through the

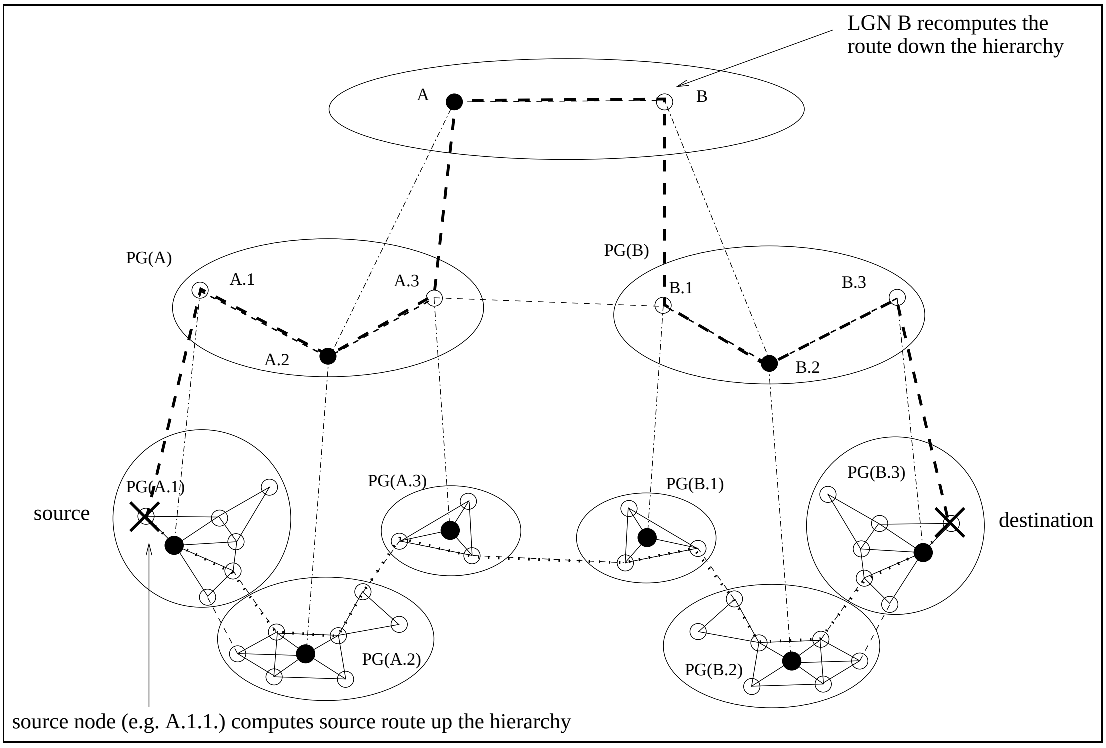

Figure 1: PNNI Routing – Hierarchical Source Routing

network by himself using well known algorithms for calculation of the shortest path. For that purpose a node administrates its own databases locally. These databases have to be as actual as possible. Via the PNNI-Flooding-Protocol information on changes within the network are deployed through a special control channel called *Routing Control Channel* (RCC) between the LGNs.

Since PNNI is designed for ATM-based networks, network routing is only performed during the establishment of ATM virtual connections. Thereby, the node connected to the source computes a hierarchically complete source route that is resolved node-by-node, group-by-group and level-by-level. A connection following this route is established using a PNNI signalling procedure.

B. IP Routing

The Internet consists of numerous areas of networks (LANs, MANs, and WANs) called *Autonomous Systems*, wherein every single Autonomous System can use a different routing technique. Basically, it has to be distinguished between the internal (within the autonomous system) and the external (between the autonomous systems) routing techniques.

In contrast to ATM networks, where virtual connections are used, in IP networks the routing decisions are made for each packet individually. Packets of the same IP session may be transmitted on different routes. In order to minimize the routing computation effort in each Internet node, instead of source routing, the packets are routed locally to the next hop using IP address masks.

Internal Routing Protocol – OSPF 2 [9] OSPF 2 abstracts the components of networks by means of a directed graph from which the shortest path can be determined. Network Areas are connected via a "backbone". Figure 2 shows the context between autonomous systems, backbones and areas.

Routing information on topology, traffic load etc. are exchanged via IP Multicast among all routers. OSPF 2 exchanges routing information between *designated* routers selected among the set of all routers. The *designated* router is responsible for the task of traffic control between the routers and interacts by exchanging the most actual topology databases with them.

A flooding algorithm is used to inform the routers on the area's topology. Each router can build up the graph for its area and compute the shortest path related to his position based on this information.

Border Gateway protocol – BGP For each area's external scope a different protocol, the *Border Gateway Protocol* (BGP), is used as the external protocol.

C. The Zone Routing Protocol (ZRP)

ZRP has been designed to fulfill the requirement of mobile ad hoc networks (MANET) carrying Internet traffic. Basically, Zone Routing is a mixture of two different routing protocols, one *proactive* and one *reactive*. This

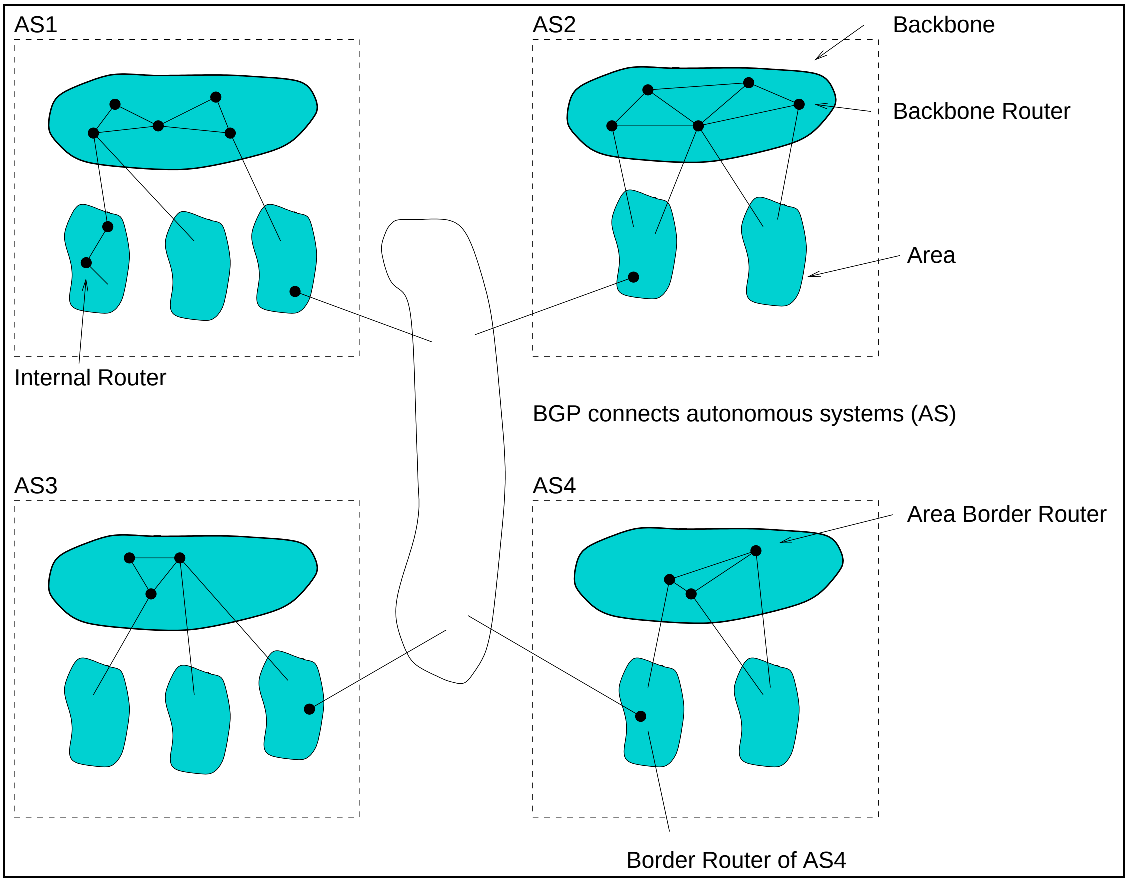

Figure 2: IP Routing – Context between autonomous systems (AS), Backbones and OSPF Areas

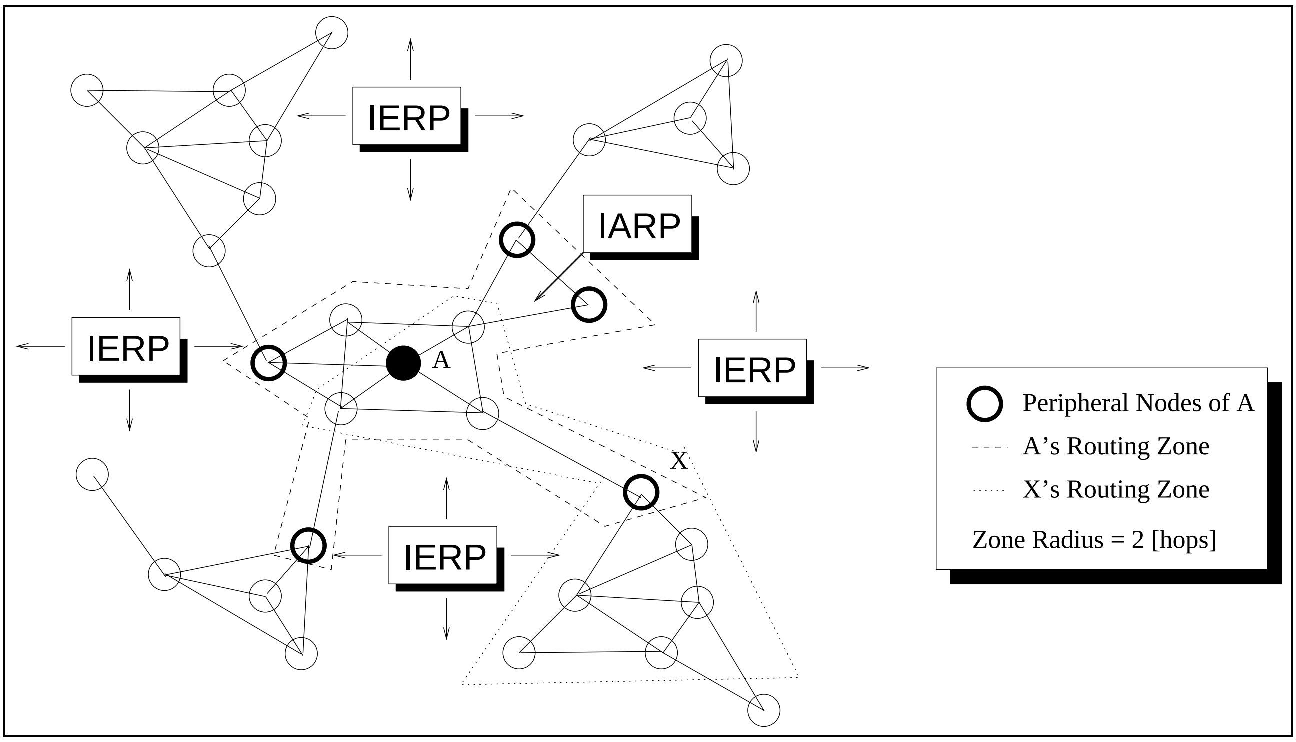

Figure 3: ZRP Routing – IARP and IERP scopes within a network

two step approach is used to cope with the high topology dynamics expected in ad hoc networks.

The whole topology is divided into the direct neighbourhood, called the *zone*, which is assigned to the proactive protocol. This protocol is called *IntrAzone Routing Protocol* (IARP). The rest of the network is assigned to the *IntErzone Routing Protocol* (IERP), which is a reactive protocol with "on demand" characteristics.

Routing Zone The Routing Zone is defined for every single node and is organized autonomously. Each node only cares for its own Routing Zone. The size of the Routing zone is determined by the zone radius h. By evaluating special messages every node can build up its own topological view of the network autonomously.

As the IARP is based on a proactive technique, routes to nodes within the own zone can be derived directly from the stored zone topology information. If a node finds that data packet is directed to a node which is not situated within the own zone the IERP is instructed with the task to find that node. The data is sent to all nodes at the border of the zone (*peripheral* nodes) and starting from their position a global flood is initiated for finding the desired route to the destination node. Each node receiving the route query performs a look-up in its database to search for the desired destination. If the node is located in the specific zone the route has been found and a reply message is sent back to the source node on the (reverse) route that has been accumulated during the flood and copied to the request hop by hop. In order to avoid loop backs specific mechanisms are supported.

III. General Comparison of Routing Platforms

From the above stated it can be derived that topology information is administered by PNNI and IP in the same way. Each network node has an precise view of its neighbourhood and an abstract view of the rest of the network. For database updates topology changes are flooded over wide areas of the network. In contrast to this, the Zone Routing Protocol is, regarding topology events and routing, the complementary case because it floods for external routes only when needed and lets topology events affect only the involved nodes that lie within a zone around the location of the specific event. Zone Routing and IP Routing are developed for routing of IP packets which are routed individually. For the use of routing platforms in WATM ad hoc networks these protocols have to be extended with procedures for establishment of ATM virtual connections which will be discussed in the full paper.

IV. Analytical Approach

In this section a mathematical analysis will provide for an overview on how the parameters of the different routing protocols influence each other in multihop ad hoc LANs.

There are two cases which have to be distinguished:

1. Low topology dynamics and many connection requests
2. High topology dynamics and few connection requests

By comparing these two cases for the different routing strategies it will be shown which platform will be most capable to adapt to the network's behaviour.

A. Network parameters

First of all, the network parameters for the calculation have to be defined.

Average distance between two nodes

$$\overline{d} = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} d_{ij}}{N(N-1)}$$

d_{ij} is the distance between node i and j ($i \neq j$) and N is the number of nodes in the network.

Connectivity factor

$$cf := \frac{\sum_{i=1}^{N} M_i}{N \cdot (N-1)}$$

M_i is the number of neighbours of node i in a network.

Density of nodes per area

$$\rho := cf \cdot (N-1) \quad [area^{-1}]$$

where $area$ is defined as the area covered by a nodes receive range r_s. This area is set to 1.

B. Routing protocol overhead estimation

The protocol overhead will be calculated for the two strategies PNNI or IP and ZRP.

Beside the network parameters mentioned in section IV.A the protocol overhead will depend on the topology change rate and the connection request rate. O is the average signalling overhead per event and will be indexed by $pnni$ and zrp, T and C for the appropriate event – either *topology change* or *connection request*.

PNNI/IP overhead estimation The overhead originated by flooding a topology event is given by the total number of nodes within the entire network N_{total}. The average overhead for signalling a connection request is the average distance between all network nodes $\overline{d}$.

Thus the total overhead for PNNI/IP is given by:

$$\overline{\mathbf{O_{pnni}}} = T \cdot N_{total} + C \cdot \overline{d} \qquad (1)$$

ZRP overhead estimation Topology events can only affect the area covered by the zone surrounding the event's location. Again, it is assumed that each node within this zone will have to broadcast one message for each event $N_{zone} = \rho \cdot h^2$. For requesting a connection the overhead is different for IntrAzone and IntErzone connections. For IntrAzone connections the overhead is the average distance within the zone $\overline{d_{zone}}$, for IntErzone connections all nodes are involved in the worst case (N_{total}). The ratio between IntrAzone and IntErzone connections is given by the ratio of the number of nodes within the zone (N_{zone}) and outside the zone ($N_{total} - N_{zone}$).

Thus the total overhead for ZRP is given by:

$$\overline{\mathbf{O_{ZRP}}} = T \cdot N_{zone} + C \cdot \left(\frac{N_{zone}}{N_{total}} \cdot \overline{d_{zone}} + N_{total} - N_{zone}\right) \tag{2}$$

C. Routing overhead calculation for clouds of network nodes

The network topology chosen for the analytical comparison is a cloud of network nodes. It is assumed that the nodes are uniformly distributed. In order to simplify the process only the centre of the network will be taken into account. H is the radius of the cloud and therefore the average distance is given by:

$$\overline{d_{total}} := \frac{\rho \cdot \sum_{i=1}^{H} ((2i-1) \cdot i)}{(H^2 \cdot \rho - 1)} \tag{3}$$

$\overline{d_{zone}}$ is derived from (3) by replacing H with the zone radius h.

By subtracting (2) from (1) the two strategies are compared. ρ is constant and the hop radius h has been varied. Figure 4 shows the difference between the two strategies for quasi stationary networks. Areas with values greater zero indicate that the ZRP overhead will be higher for the according zone radius.

Figure 5 shows the results for the case of high topology dynamics.

It can be concluded that the important parameter is the zone radius h which allows an adaptation to the topological environment.

D. Simulation forecast

Based on the formulas a forecast is given on the expected simulation results.

While the overhead for PNNI/IP is constant, the ZRP overhead varies with h (see Figure 6).

V. Conclusions

The full paper will give a more detailed performance evaluation of the ZRP in different network topologies by

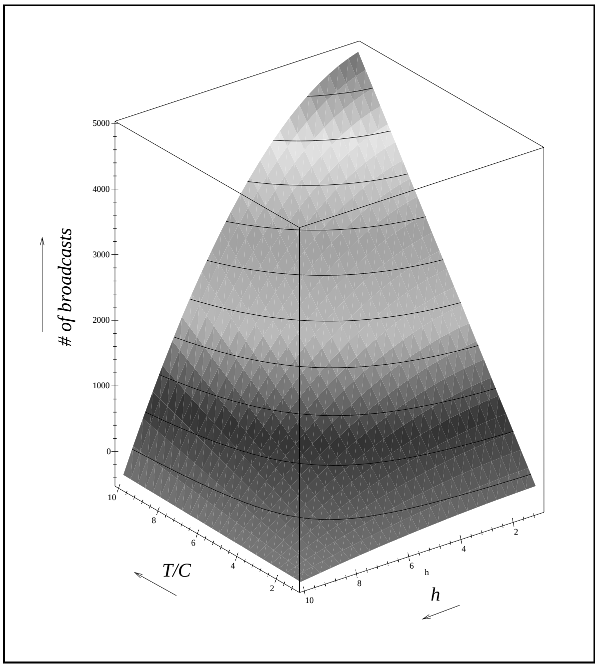

Figure 4: Difference between ZRP and PNNI/IP overhead for quasi stationary networks

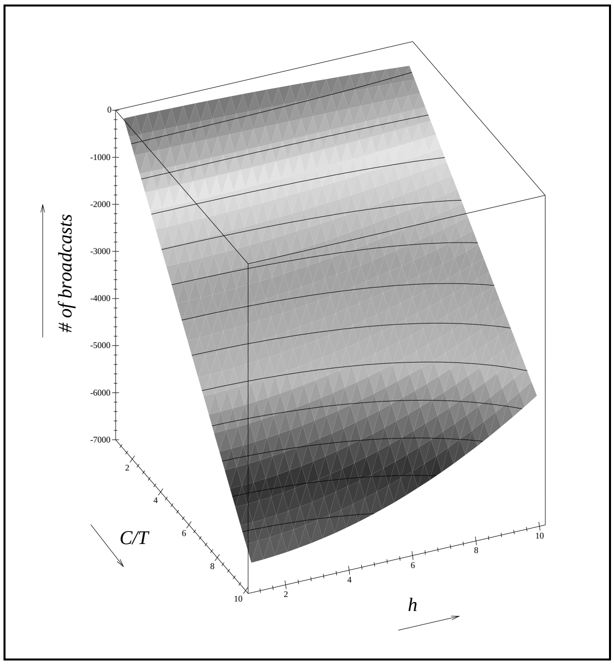

Figure 5: Difference between ZRP and PNNI/IP overhead for high topology rates

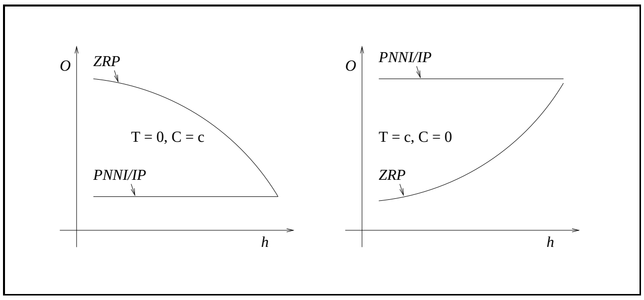

Figure 6: ZRP and PNNI/IP overhead for different zone radii

means of computer simulations.

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