Autonomic Communication and Knowledge Plane
Resource management in autonomic communication

Resource management issues in mobile ad hoc networks (MANET)

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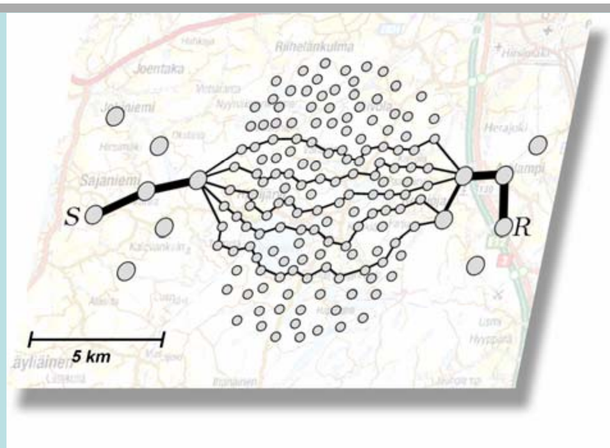
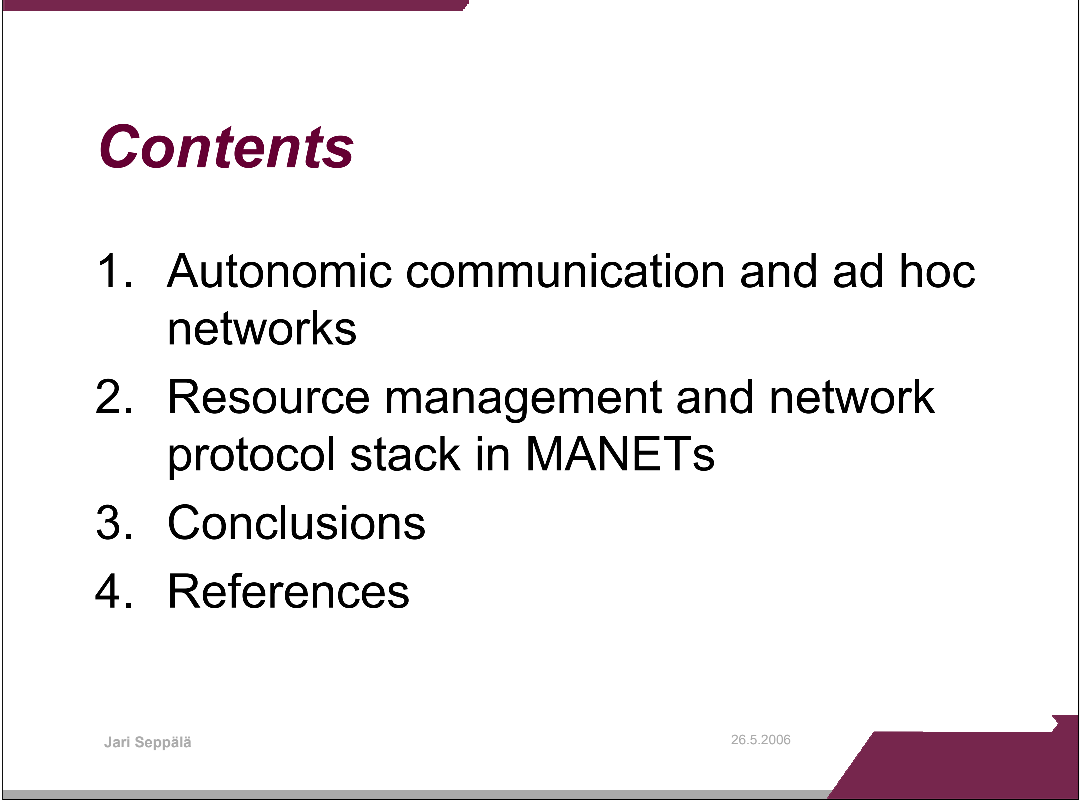


The aim of this presentation is to give an overview of resource management issues in autonomic communication and in mobile ad hoc networks.

This presentation do not concentrates to specific solutions of single resource management issues. Available technical papers and research reports describes protocols to solve some resource management issues but inter working and cooperation of different of protocols is still challenging research issue for ad hoc networks.

Ad hoc networks have various implementation areas like military, emergency and sensor applications. This presentation concentrates to resource management issues in mobile military ad hoc networks. Hence most of presented issues must be solved also in public networks.

The main perspective is network resource management in different kind of network scenarios from applications or users point of view. It is also quality of service issue. Command and control systems and different kind of users need reliable and autonomic communications network as possible.



1. Part

- Reasons to present ad hoc networks when main topic is autonomic communications and resource management
- Description of military requirements for present and future communication networks

2. Part

- Resource management issues in different layers of ad hoc network
- Main focus is in network layer (routing) and MAC-layer issues

3. Conclusions

4. References

1 AUTONOMIC COMMUNICATION AND AD HOC NETWORKS

aspects of self-management

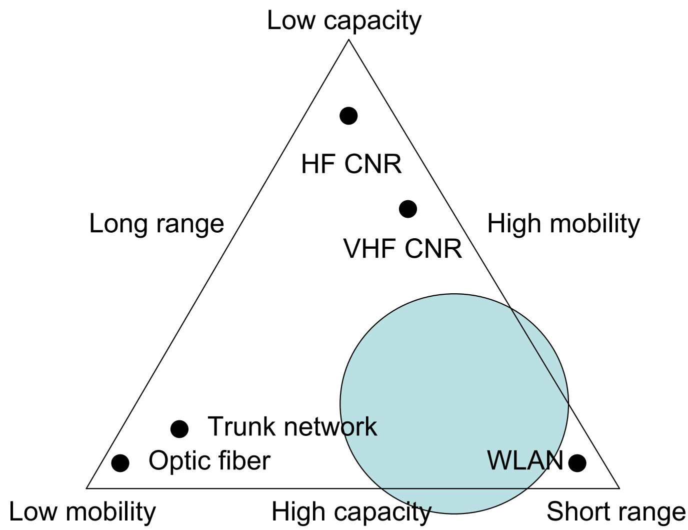
- Self-configuration
- Self-optimization
- Self-healing
- Self-protection

J.O.Kephart and D.M.Chess: The Vision of Autonomic Computing

Autonomic communication and autonomic computing are not common used terms in military command, control and communication systems. Hence main ideas of are adapted and research areas in military command, control and communication.

Communication networks like as hoc networks should have self-configuration, self-optimization, self-healing and self-protection capacity. Not only networks but also command and control devices like rugged PCs or PDAs should support high mobility and be as automatic or autonomic as possible.

Range-capacity-mobility trade off



M.Ryan and M. Frater: Tactical Communications for the digitized battlefield

Mobility is essential requirement for present and future military units. Mobile forces require communication systems with wireless communication. The ideal communication system would provide also long ranges and high capacity. Tactical telecommunication systems have typically high capacity and long communication ranges but limited mobility

-use of high capacity back bone networks (fixed) and trunk networks (field communication systems)

-use of cables, optical fibers and for example high capacity point to point radio links

-large antennas and required support from a mast

-network planning and set up of communication stations delays network mobility

-signal and headquarters units are responsible to build and maintain communication network

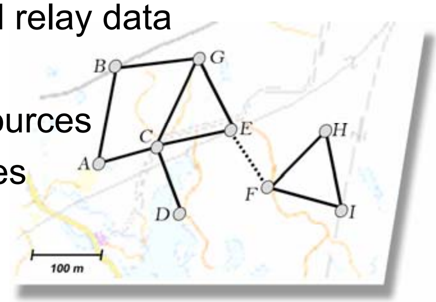
=> Communication systems in higher levels have long ranges and high capacity with low mobility

High mobility cannot be achieved using cable or optical fiber. Most common solution has been VHF- and HF-radio networks and base station services from back bone or trunk networks. Those solutions have been promising while using voice and messages. Connections are typically established by users.

=> Communication systems in lower levels have long ranges. Systems are high mobile but capacity is limited

Mobile Ad hoc Networks (MANETs)

- Self-configuration
  - Decentralized infrastructure
  - Do not need base stations
  - Nodes transmit, receive and relay data
- Self-optimization
  - Optimal use of network resources
  - Adaptive to dynamic changes



Aspects of Autonomic communications and autonomic computing are also useful Mobile Ad hoc networks. Mobile ad hoc networks need to be self-creating, self-organizing and self-administrating.

In Mobile Ad hoc networks intercommunicating mobile units (nodes) established network connections without base station, fixed network infrastructure of administrative support. In such an environment mobile nodes may have to support and cooperate with neighboring nodes to forward messages from one end of the network to another.

Mobile Ad hoc Networks (MANETs)

- Self-healing
  - terrain effects
  - node losses
  - weather conditions
  - energy management etc
- Self- protection
  - LPI, LPD
  - tolerant against jamming
  - authentication etc

Military environment differs from a typical civilian environment when ad hoc networks are considered. Some examples of differences are an uneven node distribution, hostile acts of the enemy and difficult radio propagation conditions. The circular and equal radio transmission range for all nodes is not a realistic assumption.

Low probability of interception and detection are essential requirement while using wireless links in hostile electomagnetic environment. Other self protection issues are for example authentication, access control and encryption.

The idea of military Ad hoc networks is promising but present unique advanced challenges including mobility management, effective routing, data transport, security, power management and quality of service provisioning.

2 RESOURCE MANAGEMENT AND NETWORK PROTOCOL STACK IN MANETS

Application layer	Resource allocation for applications
Transport layer	Efficient use of transport protocols TCP, UDP. RTP
Network layer	Efficient routing, IPv6, QoS
MAC layer	Selection and efficient use of MAC protocol
Physical layer	Selection of physical media, transmission power and frequency management

Physical layer and MAC layer:

Abundant bandwidth is available in wired networks due fiber optics and wavelength division multiplexing (WDM) technologies. In wireless networks the radio band is limited and data rates are much less than what wired networks can offer. In Mobile ad hoc networks routing from source to a destination node is based on multi-hopping. These networks have quite many challenges because of uncertainty of radio interface, available bandwidth and use of batteries.

Network layer:

Efficient selection of routing protocols (different kind of network structures), address management, mobile management, and quality of service issues

Transport layer:

The main objective of the transport layer protocols are setting up and maintain end-to-end connections, delivery of data packets, flow control, and congestion control. Examples are for instance connectionless UDP (without flow and congestion control, do not take into account the current network status) and connection-oriented TCP (challenges like frequent path breaks, presence of stale routing information, high channel error states and frequent network partitioning=> packet losses => congestion control and avoidance algorithms => poorly throughput).

Application layer:

Different application has specific QoS requirements. For example in military applications LPI and LDP, efficient routing during fading and disturbed radio channel conditions, low or minimum energy consumptions, high mobile network

2.1 Data link layer and MAC

- Communication through the wireless medium
- Shared channel or multiple channels
- Distributed arbitration of shared channel

The primary responsibility of a medium access control protocol in ad hoc network is the distributed arbitration of the shared channel for transmission of packets.

Nodes in MANET communicate through the wireless medium. If a shared channel is used, neighboring nodes must contend for channel. Neighboring nodes hear the transmission until the channel is free. Even when multiple channels are used, the quality of transmissions may be degraded due to interference.

Connectivity between nodes cannot be improved by simply increasing the radio transmission ranges of all nodes, because then neighboring nodes disturb each other, and thus MAC level throughput decreases. Some solutions like orthogonal use of bandwidth are available to decrease that kind of disturb. Another challenge is the lifetime of batteries while using high transmission power.

(Murthy and Manoj, Ad Hoc wireless Networks: architectures and protocols, Prentice Hall Professional Technical Reference, New Jersey, USA, 2004)

(Mika Nordman, Quality of Service in Tactical Ad Hoc Networks, Tampere University of Technology, Tampere, Finland, 2006)

Major issues in MAC protocol design

- distributed operation
- synchronization
- hidden and exposed terminals
- throughput
- access delay
- fairness
- real-time traffic support,
- resource reservation
- ability to measure resource availability
- capacity for power control
- adaptive rate control and
- use of directional antennas

Major issues in MAC protocol design are distributed operation, synchronization, hidden terminals, exposed terminals, throughput, access delay, fairness, real-time traffic support, resource reservation, ability to measure resource availability, capacity for power control, adaptive rate control, and use of directional antennas. All these issues should cater to implementing efficient MAC protocols for ad hoc networks.

2.2 Network layer and routing

- best route but…
- distributed resource usage across the network nodes
- large overheads to solve the routing problem
- the number of routing packets increase dramatically in the network size increases

There are numerous protocols for ad hoc networks. The protocol to be chosen must cover all states of a specified network without using too much network resources by protocol overhead traffic.

Routing challenges while taking in consideration the special network characteristics like mobility, limited energy, limited bandwidth, limited prosessing power and high bit-error rate.

Classification of routing protocols

- Table-driven - Source-initiated
- Proactive – Reactive
- Topology-based – Destination-based
- Multi-channel – Single-channel
- Uniform – Non-uniform
- Unicast – Multicast - Geocast

Table-driven – Source-initiated (Proactive – Reactive)

Table-driven routing protocols try to maintain consistent (up-to-date) routing information from each node to all other nodes. Nodes maintain table (or tables) for routing information. Nodes respond to network topology changes by propagating route updates throughout the network.

Source-initiated on-demand protocols create routes only when routes are needed. When a node requires a route to a destination, it initiates a route discovery process. The process is completed when a route is found or all possible route permutations have been examined. There will be also route maintenance procedure to keep up the valid routes and to remove invalid routes.

Topology-based – Destination based

Topology-based protocols use the principle that every node in a network maintains large scale topology information (principle is used in link-state protocols). Destination-based protocols only maintain topology information needed to know the nearest neighbors (principle is used in distance-vector protocols).

Multi-channel – Single-channel

It is also possible to divide protocols according to communications model. In this allocation protocols are for multi-channel (TDMA, CDMA) or single-channel (CSMA) use.

Uniform – Non-uniform

In uniform protocols there is no hierarchy in network, all nodes send and response to routing control messages at the same manner. In non-uniform protocols the control traffic burden is reduced by separating nodes in dealing with routing information. It is possible to divide non-uniform protocols into two categories: Protocols focuses routing activity on a subset of its neighbors and protocols in which the network is topologically partitioned.

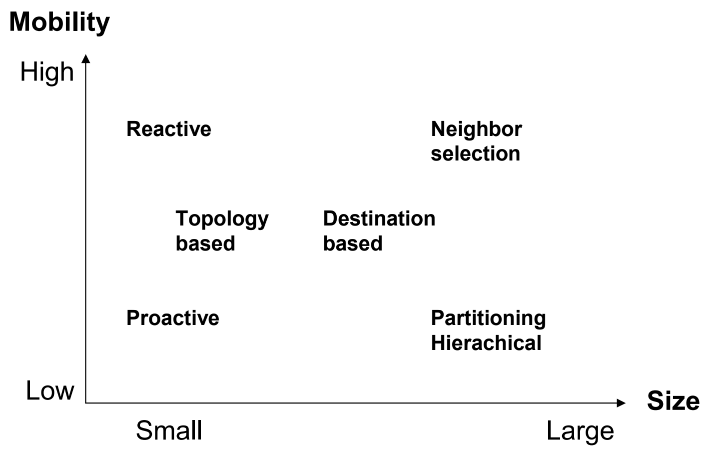
Unicast – Multicast – Geocast

Protocols can be divided according the type of cast. Protocols can operate at unicast, multicast or geocast situations. In unicast one source transmits routing messages to one destination. Unicast protocols are the most common in ad hoc networks.

Multicast protocols construct a routing tree or a mesh from one source to several destinations. These protocols are also needed to keep up the information of joins and leaves to multicast group.

Geocast protocols deliver data packets for a group of nodes which are situated on specified geographical area.

Suitability of different kind of Ad hoc routing protocols



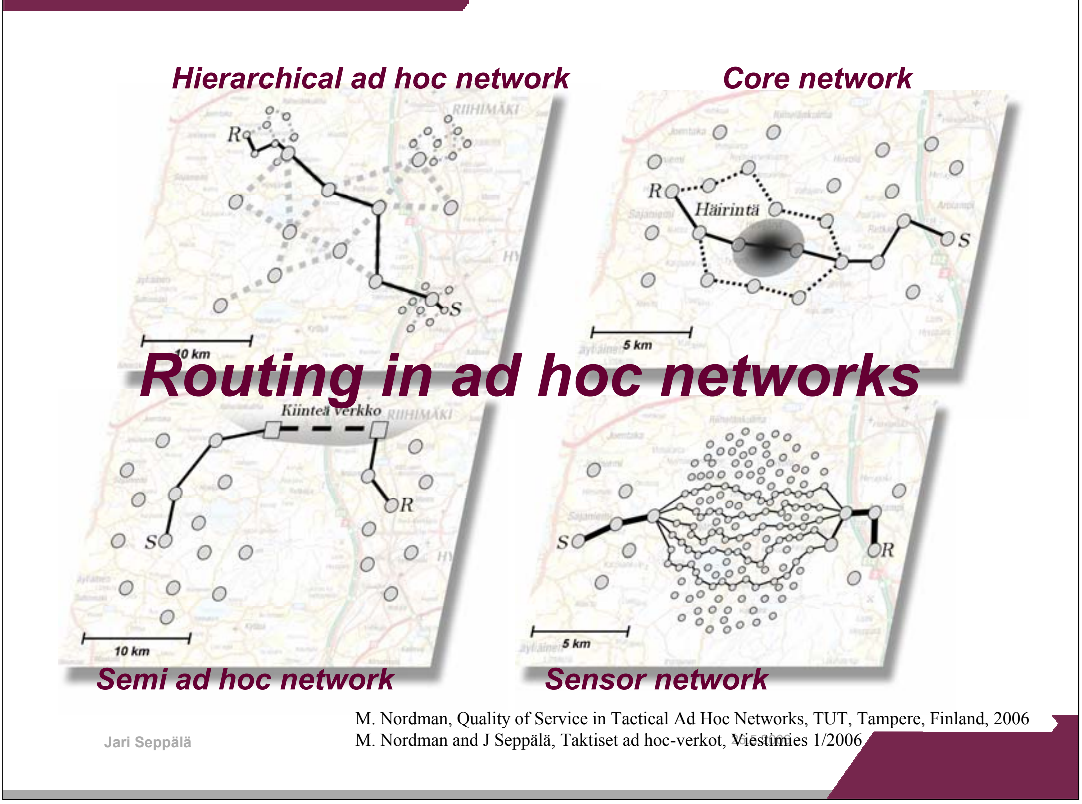
P Kuosmanen: Classification of Ad Hoc Routing Protocols

Cost functions

- Hop count is not enough
  – link capacity, latency, link utilization percentage, terminal energy
- Cost functions must be adapted to route calculations

In ad hoc networks there is a wide variety of issues to consider such as link capacity, latency, link utilization percentage, terminal energy etc.

So it is not enough to take only considerations to hop count. Best route could be calculated by one or several functions. In some quality of service situation the best route should be the one with high bandwidth and some other scenario the use of energy could be essential.



Following examples describes self-organization, self-optimization, and self-healing capacities of ad hoc networks.

Ad hoc networks are regularly hierarchical in military use. Some kind of trunk or core network nodes could be used to connect other nodes to the common ad hoc network. Higher level nodes are typically vehicle mounted. Higher transmission powers, special antennas are available.

Ad hoc networks have number of threats in military use and hostile environment. Nodes S send data to node R. Route between nodes are found and established and routing information is stored by the intermediate nodes. In this scenario the enemy jams the data transferring and two nodes are disabled. The nodes on the route detect the jamming and establish new route or routes for communication.

While military forces moving from area to another is fact that all the nodes are not moving at the same time. Terrain obstacles and large operation areas may effect situations in which the network is fragmented. Higher transmission power would decrease the probability of detection and subsequent jamming. Picture of semi ad hoc network describe the use of other network while ad hoc network is fragmented.

Picture of sensor network describes situation like semi ad hoc network. Sensor network is used to connect fragmented ad hoc network. Picture describes also multipath routing and communication while single routes can’t ensure the quality of service.

Conclusions

- Lot of solutions and guidelines for all layers
- Partial solutions for whole network or nodes
- Research and development towards demonstrations and demonstrators
- Cross-layer design to solve challenges

Layered structure of presented protocols

-resource allocation for applications

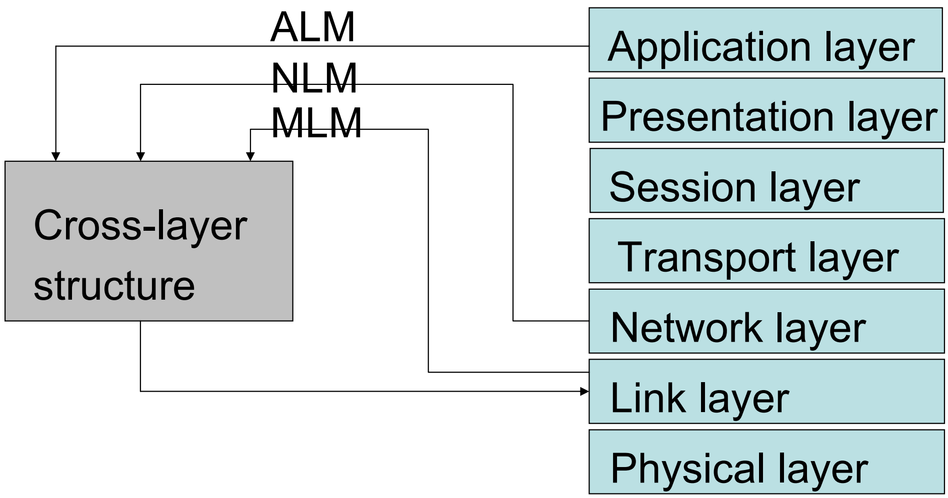
-Efficient use of transport protocols

-Network layer issues like efficient routing, IPv6 and QoS

-Efficient use of selected MAC protocol

-Selection of physical media, transmission power and frequency management

Although hierarchical protocol design has been a success. Creation of stand-alone protocols, without referencing the higher or lower layers has facilitated development. However, many questions and practical details span several layers. Challenging issues are cooperation of protocols in different layers. One solution is cross-layer design. Martinez has presented a model which is based on the division of the network features in three main groups.



Application layer metrics (ALM)

The objective of ALM is the classification of the traffic type in different service classes

MAC layer metrics (MLM)

The MLM is related to the state of the MAC layer buffers and offers information about the load of each link (number of packets per priority per link)

Network layer metrics (NLM)

Includes metrics like network topology, paht gains, antenna type or battery state

Key words of military ad hoc network research

Support for real-time interactive session

On the move

Energy efficient

Jamming tolerance

Disruption tolerant

Mobile backbone

Security management

Intrusion detection

Survivability

QoS awareness

Routing efficiency

Dynamic addressing

Adaptive middleware

Secure routing

Header compression (IPv6)

References

1) M. Smirnov: Autonomic Communication, FET consultation meeting on Communication paradigms for 2020, Brussels, 2004
2) Fraunhofer, Institute for Open Communication Systems: Autonomic Communication, Research Agenda for a New Communication Paradigm, 2003
3) IBM's Perspective on the State of Information Technology: Autonomic Computing
4) J.O.Kephart and D.M.Chess: The Vision of Autonomic Computing
5) M.Ryan and M. Frater: Tactical Communications for the digitized battlefield
6) P Kuosmanen: Classification of Ad Hoc Routing Protocols
7) M. Nordman: Quality of Service in Tactical Ad Hoc Networks, TUT, Tampere, Finland, 2006
8) M. Nordman and J .Seppälä: Taktiset ad hoc-verkot, Viestimies 1/2006
9) O.H. Hussein: Probability Routing Algorithm for Mobile Ad Hoc Networks' Resources Management, IEEE Journal on selected areas in communications, vol 23, No 12, 2005
10) M. W. Subbarao: Ad Hoc Networking Critical Features and Performance Matrics, Wireless Communications Technology Group, NIST, 1999
11) I. Martinez, J. Altuna and L. Arnaiz: A New Cross-layer Design for Ad Hoc Wireless Networks with QoS support, Scandinavian Workshop on Wireless Ad-hoc Networks, Stockholm, Sweden, 2004