Towards analysis of IP communication in a constrained environment of tactical radio networks

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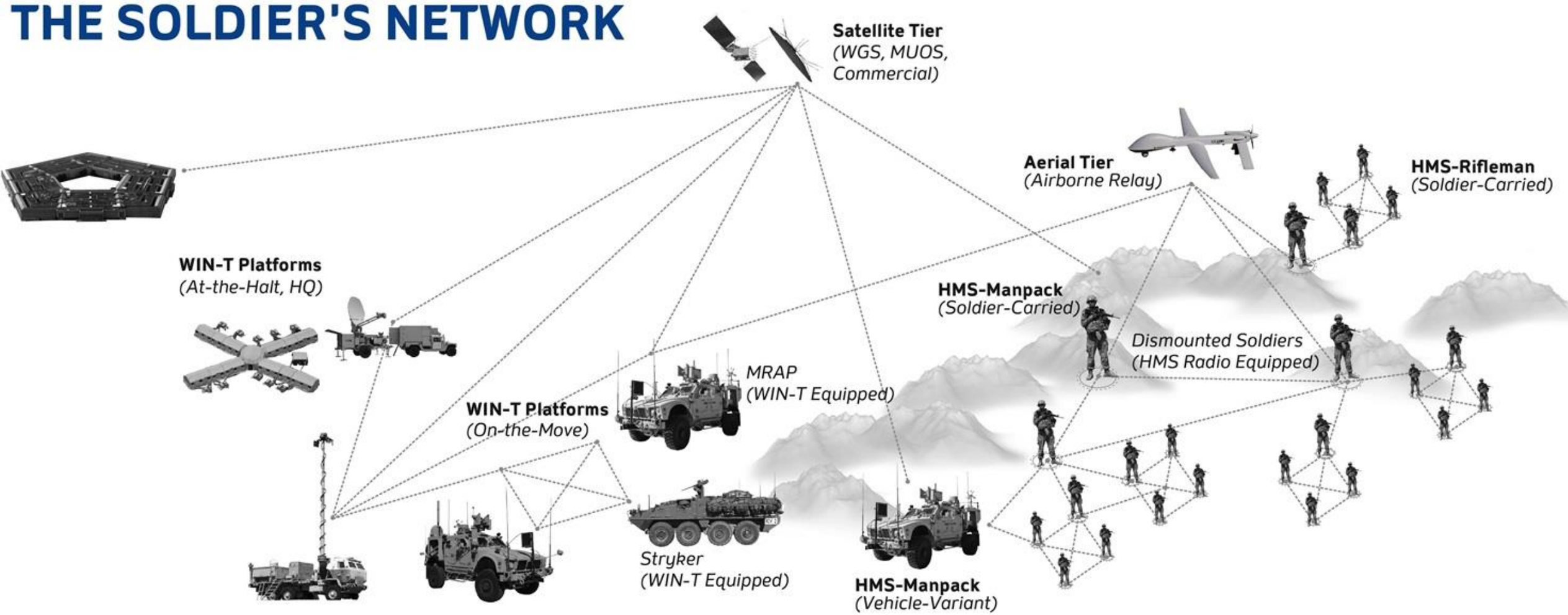
Introduction

- Battlefield tactical radio networks interconnect combat units by providing voice communication simultaneously with a limited amount of data traffic.
- New battle management systems are complex network-centric platforms integrating various components and interconnecting different edge networks.
- There is a tendency to employ standard Internet protocols for communication within the Battle Management System network.
- TCP/IP communication in tactical networks is addressed by NATO STANAG 5066 specification.

THE SOLDIER'S NETWORK



Typical Handheld radio

Frequency range
30-512 Mhz
Moduation
FM, AM, CPM
Tx Power
5W
Channel bandwidth
25kHz, 250kHz
Encryption
AES
Interfaces
Ethernet, USB, Serial

Technologies

- WIDEBAND LINKS
  Expensive adoption of new technologies offering wide-bandwidth communication channels is often not among the available options.
- NARROWBAND LINKS
  Even a new generation of tactical radio technology designed according to MANET principles does not provide enough capacity to run TCP/IP applications.
- TCP/IP
  Customers require the adaptation of TCP/IP in BMS networks. Because they hope that interoperability would be possible.

Radio Characteristics

- Decentralized, auto-forming, multi hop MANET
- Single channel, up to 270 kbit/s data rate (low VHF)
- The radio network communication is thus:
  - at low speed
  - changing transmission capacity, and
  - affected by substantial error rates.
- Also, turnaround time is significantly larger than in the typical Internet environment.

  Try to open even a simple web page with EDGE GSM connection.

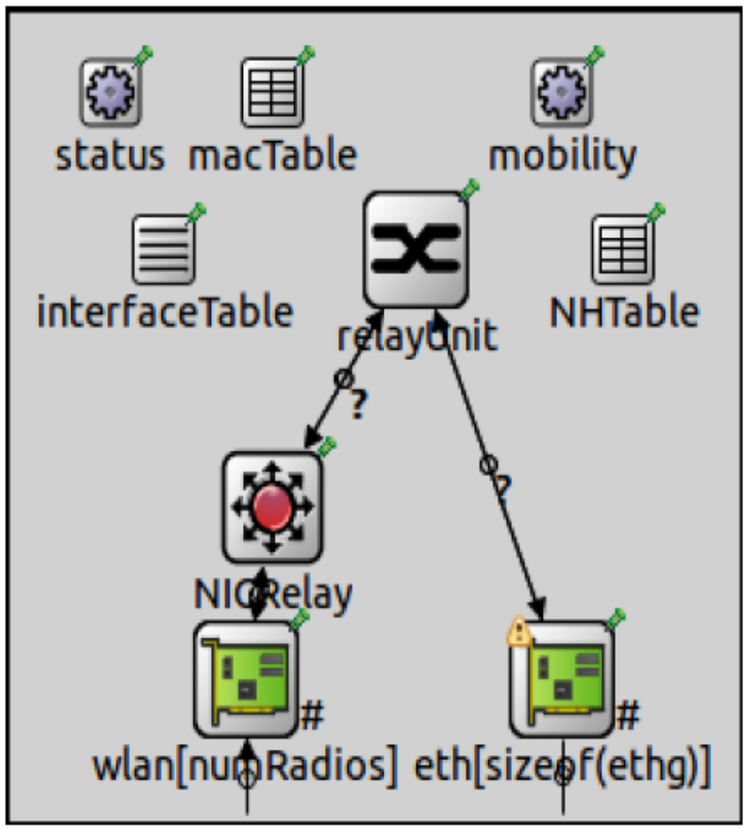
Internet protocols

- As the majority of Internet applications rely on the reliable data transfer, they utilize Transmission Control Protocol (TCP) for data delivery.
  - TCP uses retransmission and window-based flow control.
  - TCP can adapt to network conditions but in a very constrained environment this may not be enough.
- Other communication (even using much simpler protocol) can be a problem too:
  - ARP – response to request required within predefined time
  - DHCP – possibly initiating multiple negotiations if timeouted

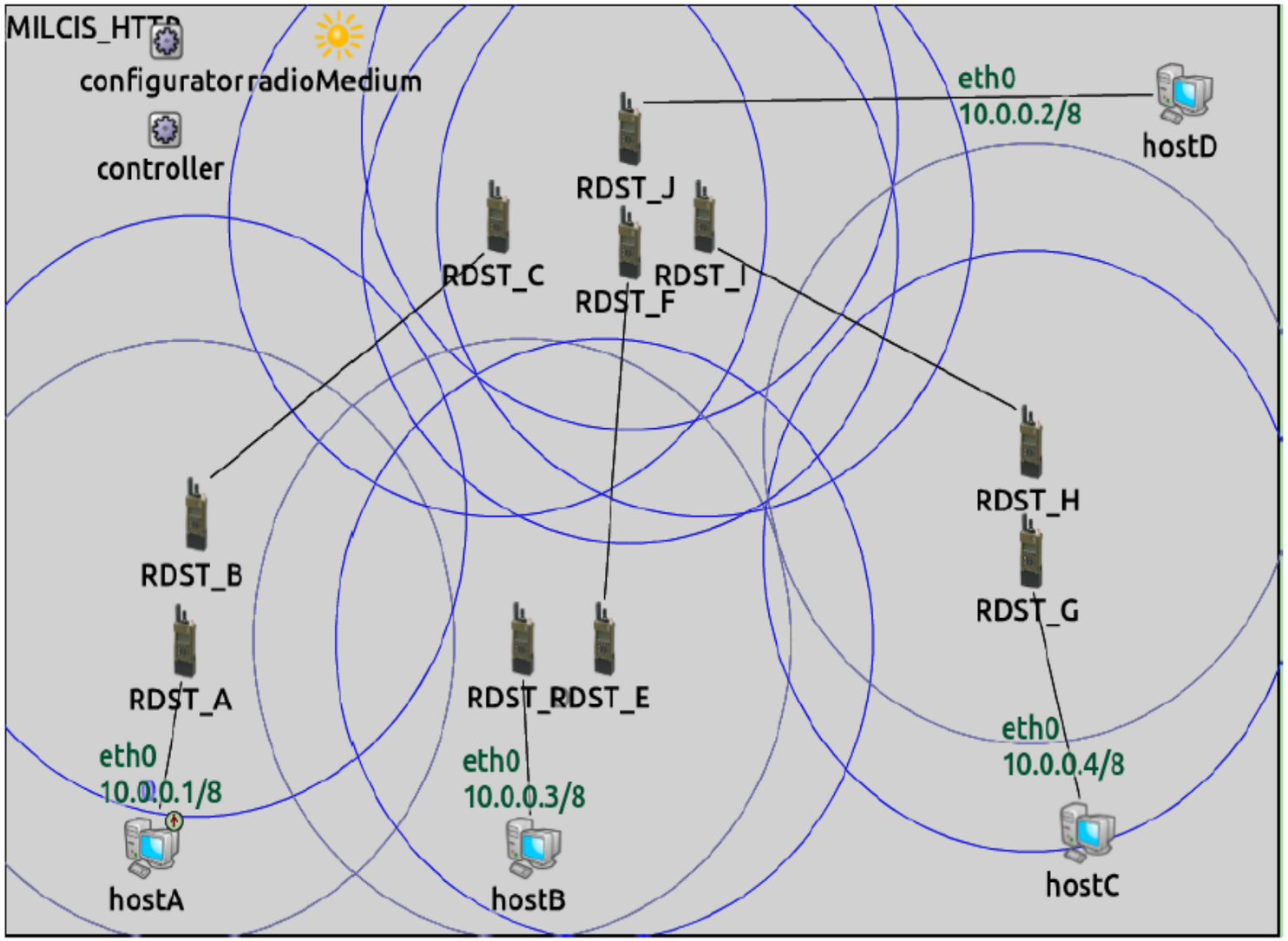
Contribution

- We provide a simulation analysis of the above mentioned problems.
- Our aim is to design a framework for estimating achievable parameters of TCP/IP communication in narrowband radio networks.
- The tool that can be used as a cheap but accurate method for evaluating the possibility of running TCP/IP applications in tactical radio networks.
- The developed framework was used to conduct a preliminary analysis of ARP and DHCP communication, and to estimate the performance characteristics of TCP.

Simulation Model



(a) RF-node model



(b) RF-network model

Networks

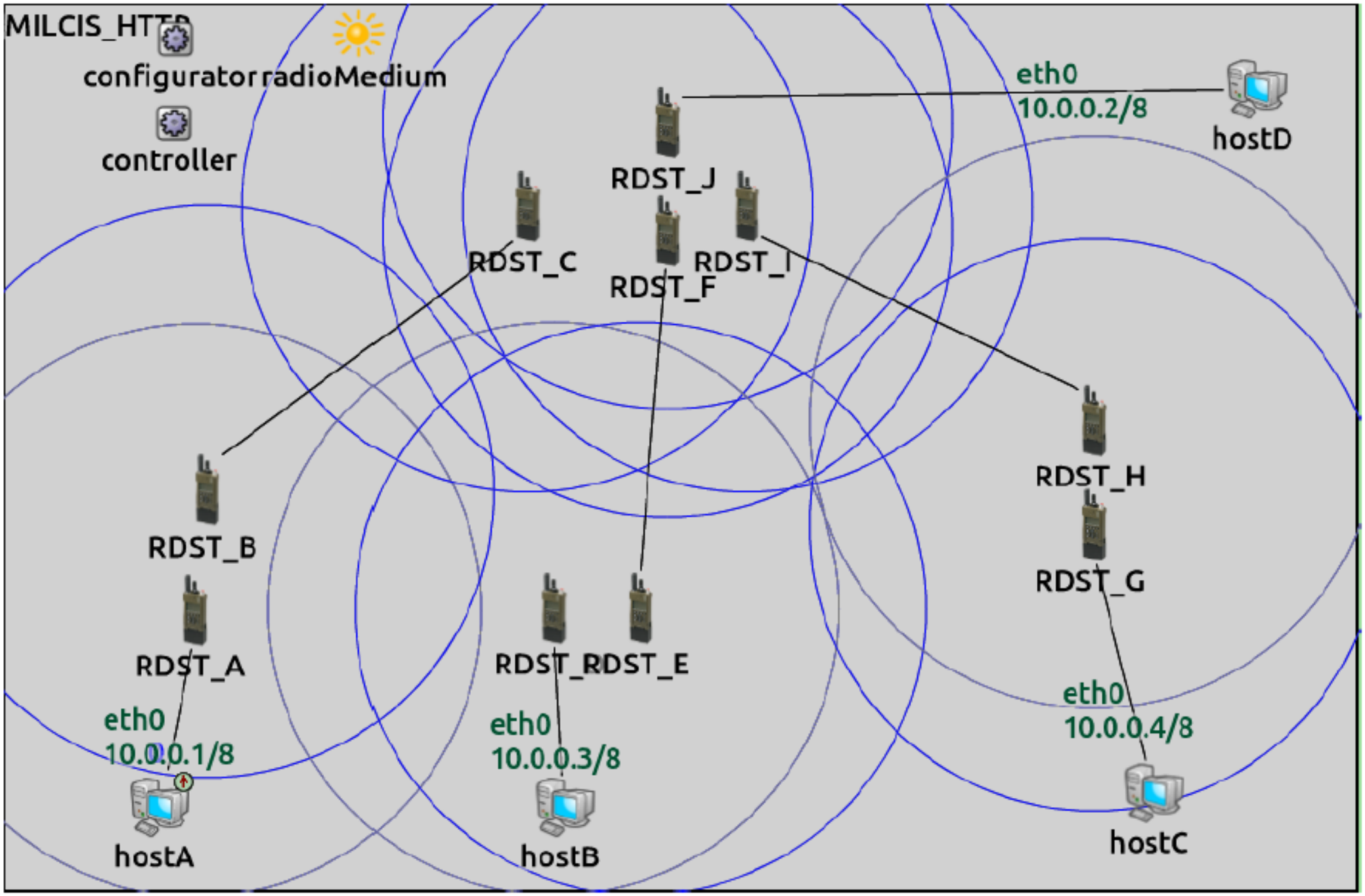
We created simulation models of networks in OMNet++.

- Radio network
  - Decentralized, auto-forming, multi hop MANET
  - Single channel, up to 270 kbit/s data rate (low VHF)
- Ethernet networks
  - Single Ethernet interface for connecting devices to RF-node
  - RF-node runs RT OS with full TCP/IP stack thus communication of RF-node to connected device is not an issue.

Parameters

- The radio network uses TDMA control
- The typical capacity in this kind of networks is 20-96kbps.
- In simulation we considered the following parameters:
  - Number of slots
  - Slot length
  - Queue size
  - Location of RF Nodes
  - Error rates

Routed vs Switched



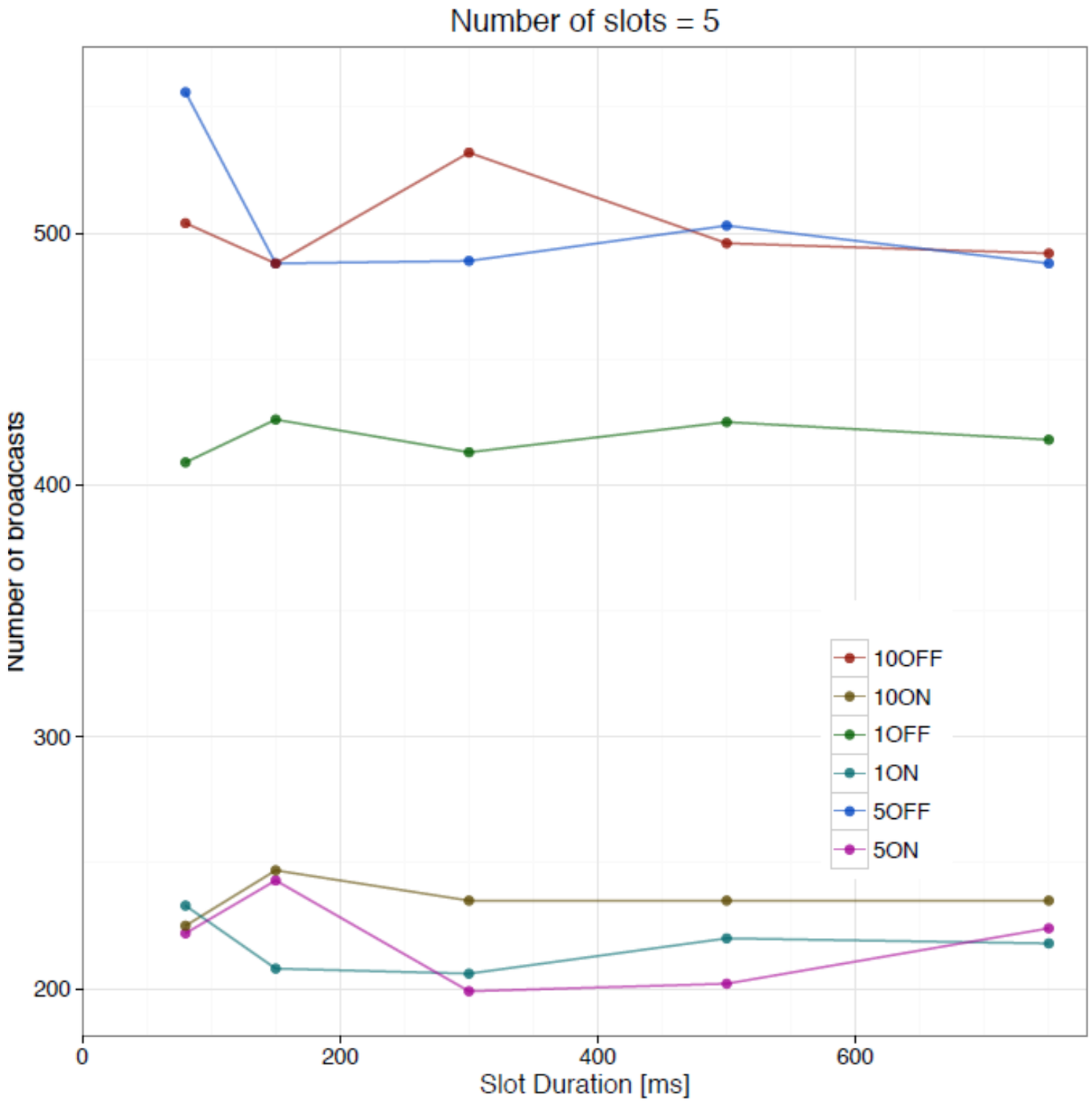
Analysis and Results

- We analyzed three protocols: ARP, DHCP, and TCP
- We used different parameters of the simulation runs:
  - numSlots
  - slotDuration
  - queueLength
- We run the simulation several times
- In the paper we published results only for switched architecture.

Address Resolution

- The problems may arise even on lower layers:
  - ARP uses a simple mechanism of request/reply to obtain MAC address for IP address.
  - ARP records are put in ARP cache for a limited time.
    - ARP expiration means that ARP procedure needs to be repeated.
  - ARP is send as a broadcast.
    Though RF network supports multicasting, this still consumes resources.
- We analyzed the case w/o ARP Proxy.

Broadcast reduction

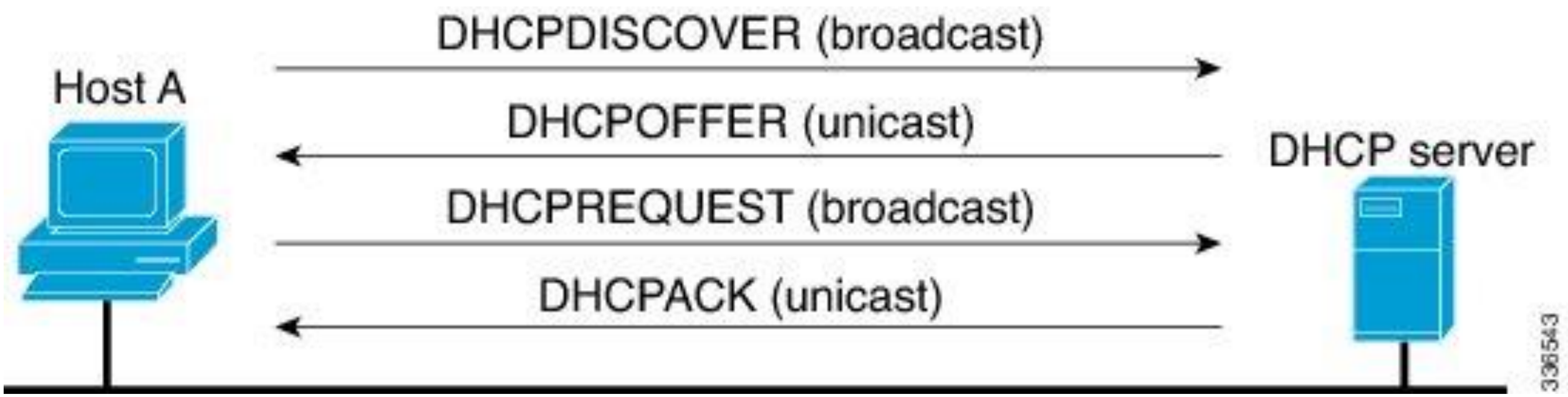


No ARP Proxy

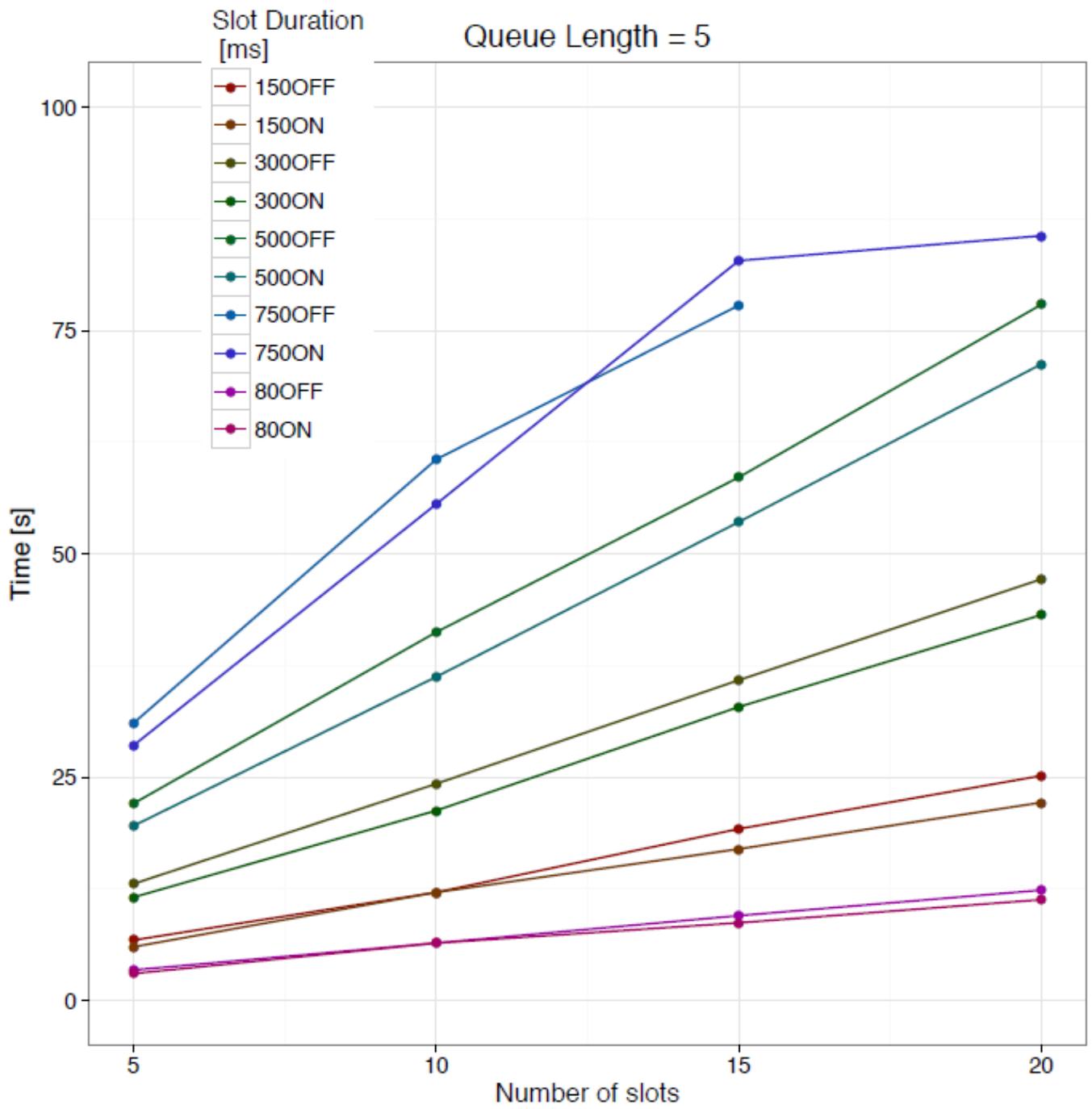
ARP Proxy

DHCP

- DHCP is unreliable and uses timers to detect lost messages.
- We implemented simple mechanism to improve the performance – when new DHCPDISCOVERY is received in RF node, we check if previous is not in queue.
- This modification enable to complete DHCP in high latency scenarios.



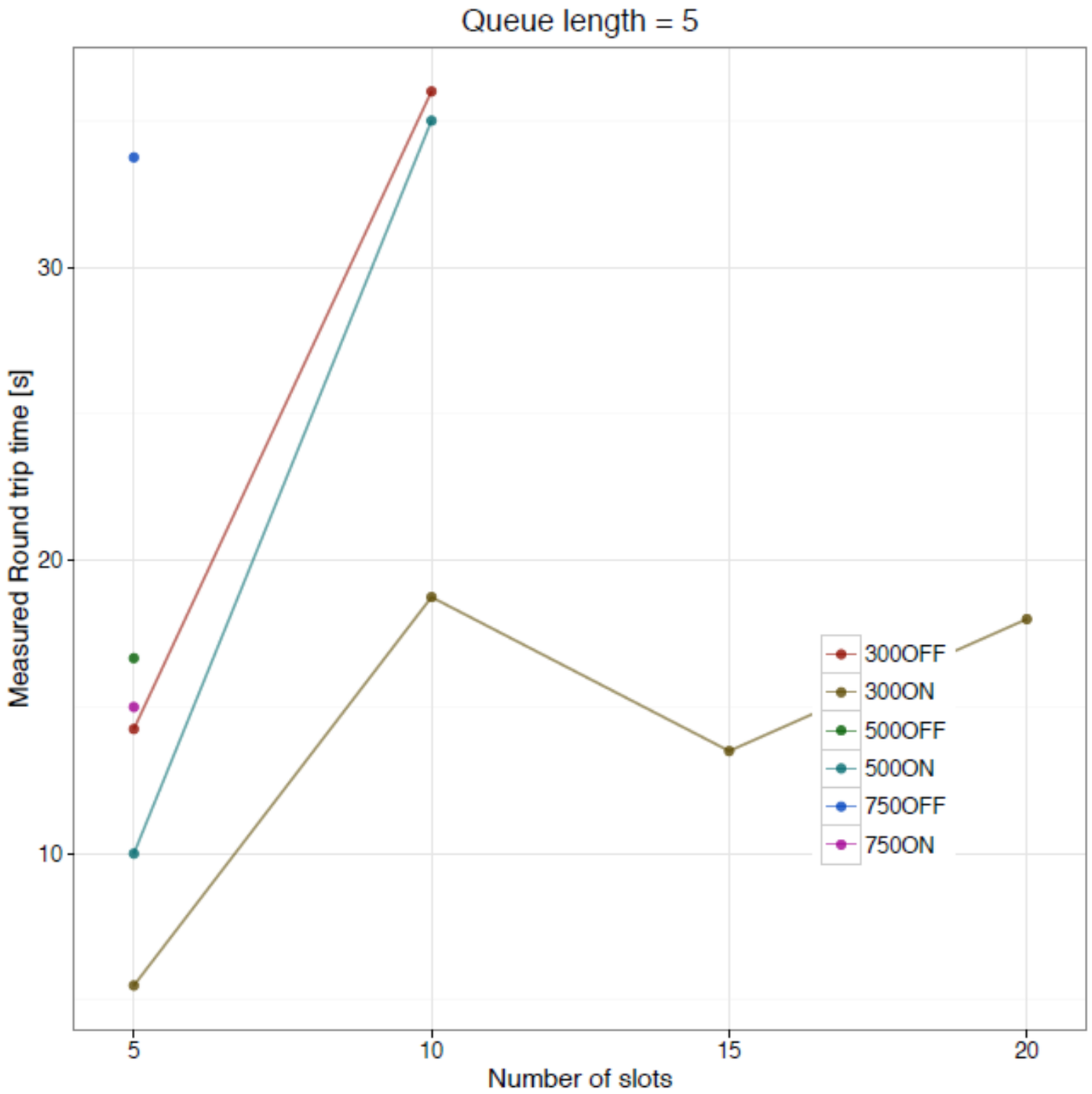
DHCP Completion



TCP

- TCP can cope with harsh network conditions by reducing sending window.
- Throughput depends on latency and the window size.
- We measured latency in form of RTT for different parameters
  - Considering segment size 1400B:
    - For more than 5 hosts the average RTT increases above 10s
    - At least 40kbps is required to keep TCP session for more than 10 nodes
    - In all cases average RTT is in terms of seconds
  - Reducing RTT requires to reduce segment size

RTT


Queue length = 5
Measured Round trip time [s]
30
20
10
5
10
15
20
Number of slots
300OFF
300ON
500OFF
500ON
750OFF
750ON

Discussion

- The simulation model reveals the following problems:
  - A combination of low bandwidth and high latency is a major problem for most of the protocols.
  - TCP was originally developed for WAN and thus it can cope with high latency and low throughput. It can keep session for a long time.
  - Considering the session as death depends on a timer which is implementation dependent (or configurable).
- Adaptation of TCP/IP stack for the constrained environment is necessary.

Summary

- The simulation model can be used in further analysis of:
  - Different configurations
  - Various situations (number of nodes, visibility, etc.)
  - Protocols for radio network (modifications)
  - Architecture design (router/swiched/hybrid)
- Cheaper than experimental environment
- Because of domain, experimental environment is still necessary.