Should We Use the Default Protocol Settings for Networks of Constrained Devices?

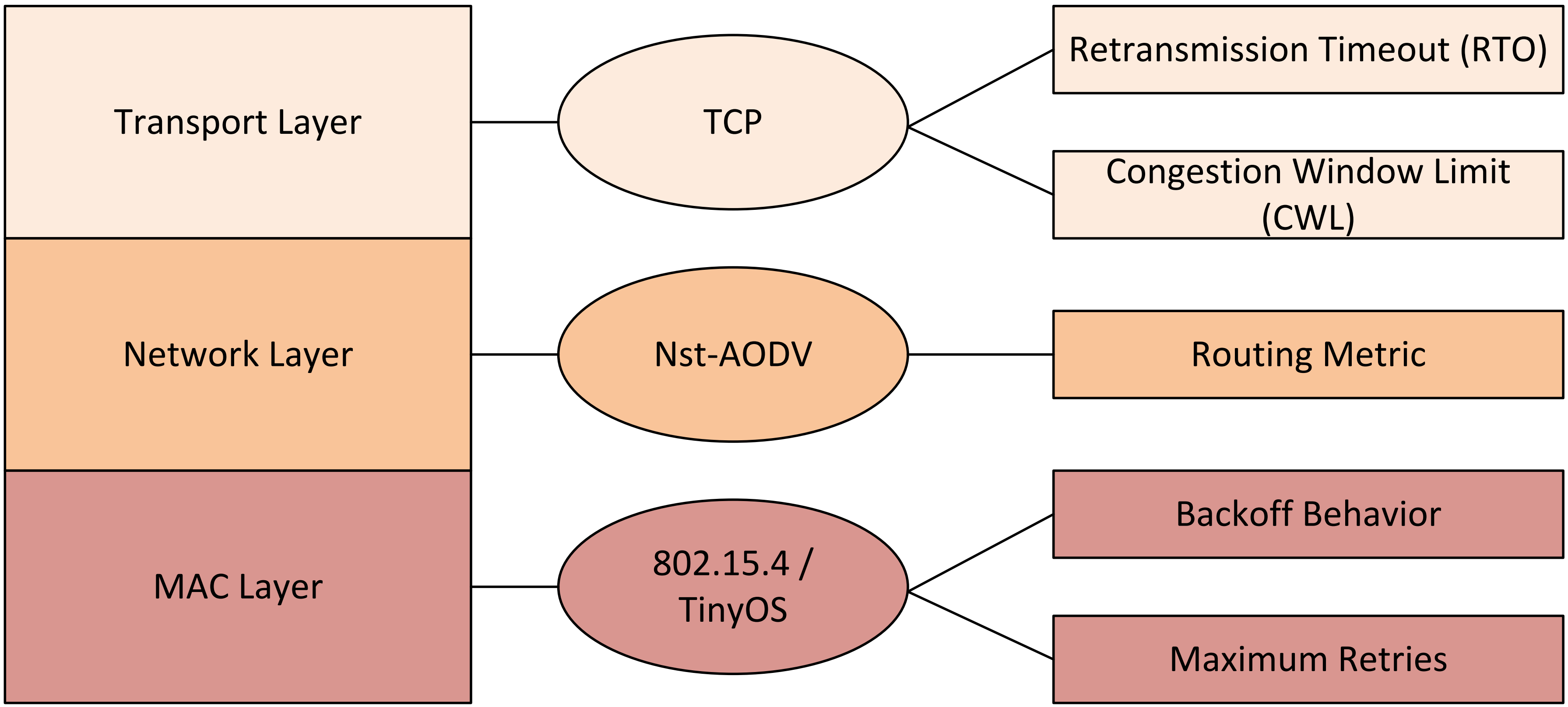
August Betzler, Carles Gomez, Ilker Demirkol, Josep Paradells

Wireless Network Group
Universitat Politècnica de Catalunya
Barcelona, Spain

Introduction

- Constrained devices are playing a crucial role in current investigations as the Internet of Things.
- Multihop end-to-end transmissions require cooperation of several layers of the communication protocol stack. At each layer different mechanisms and protocols are used, each of them with a set of default values.
- We investigate how these layers are designed, taking a look at default configurations of the layers' parameters/mechanisms and comparing them to alternative possibilities. We also explore cross-layer effects between layers and how they affect the performance.
- Investigation and evaluation is carried out in a real testbed in a laboratory environment.

Which criteria are analyzed?



Default settings

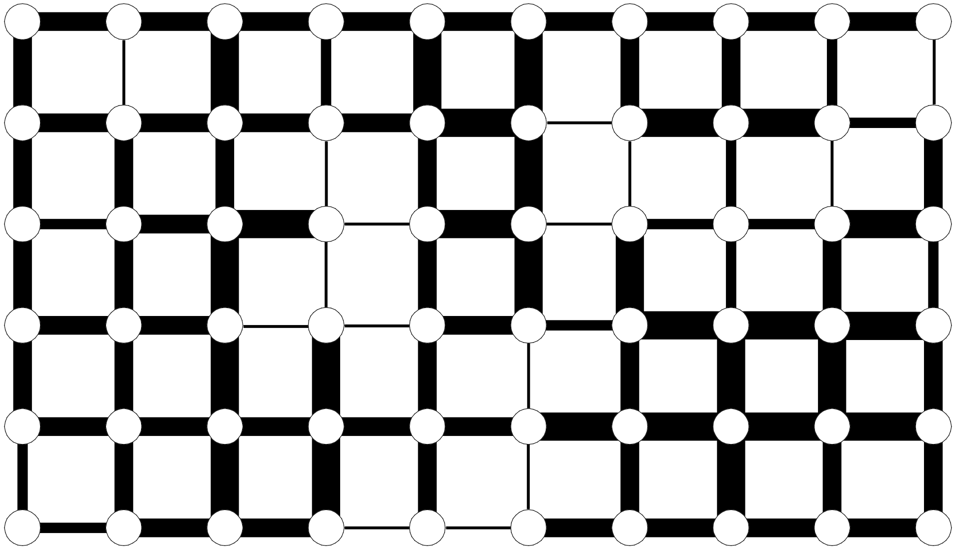
LAYER	CRITERION	DEFAULT SETTING	DEFINED BY
MAC	Backoff method	Intial long, subsequent short	TinyOS
	Max retries	3	802.15.4
Routing	Routing metric	Min. hop count	AODV
Transport	CWL	8	Memory limit
	RTO calculation	Adaptive (SRTT, RTTVAR)	RFC6298

Sensor grid

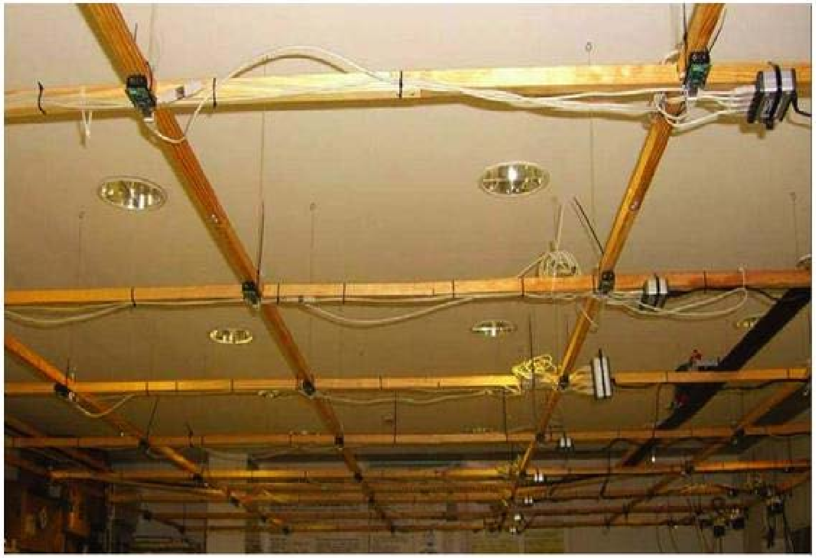
- The grid consists of 60 TelosB motes (6x10).
- All nodes are connected via USB to a desktop PC, supplying them with power and allowing to interchange serial data.
- Transmit power is set to minimum to increase number of hops along routes between two endpoints.
- Tests are done at night to reduce user interferences. The radio is configured to use channel 26 (2480MHz ±1MHz).
- Typical indoor effects on signal quality and propagation can be observed:
  - Varying link qualities
  - Multipath propagation

Sensor grid

Snapshot of Link Quality Indicator values (LQI)



View on the grid from below

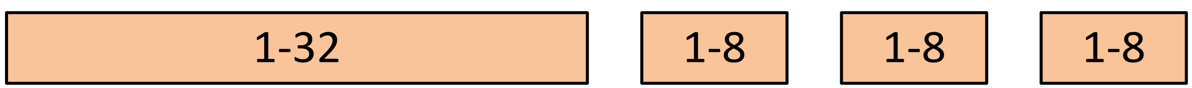


Test scenarios

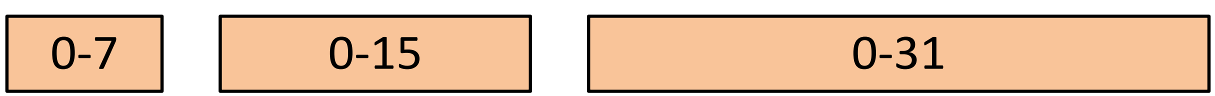
- Single transmission of a large file (44kB) between two nodes of the grid:
  - Static scenario: Over predetermined routes of different lengths.
  - Dynamic scenario: By letting nst-AODV choose the routes between the two endpoints and allowing changes of the route during a file transfer.
- Routelength and CWL are variable parameters for tests.

MAC Layer – backoff behavior

- MAC layer backoff:
  - TinyOS backoff mechanism:
    - One (long) backoff interval (1-32 backoff units (BUs))
    - Subsequently shorter backoff intervals (1-8 BUs)

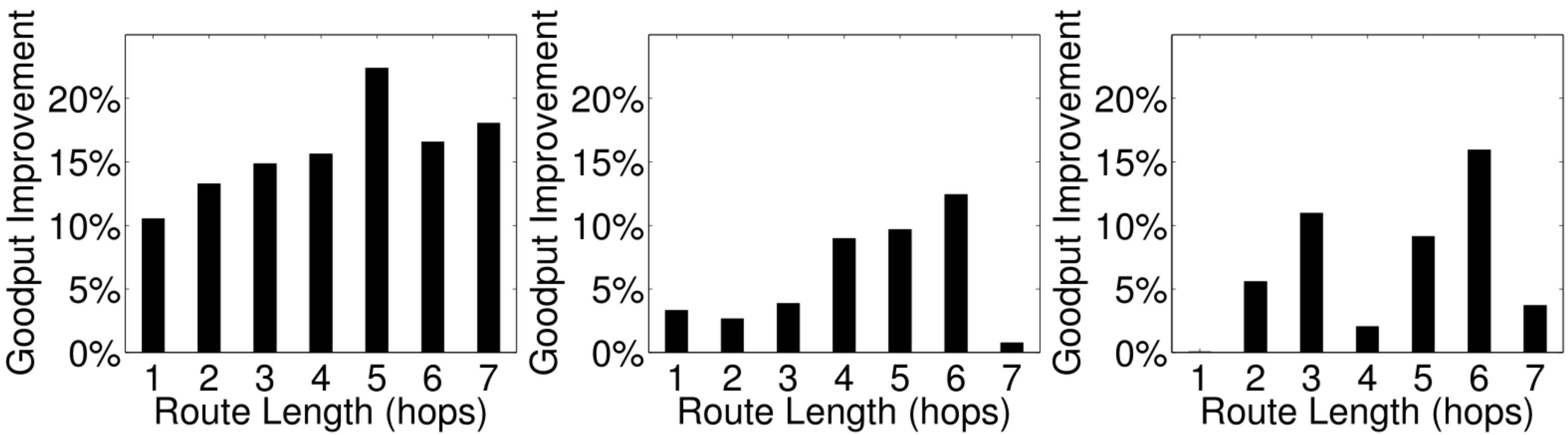


  - Exponential backoff mechanism (as in IEEE 802.15.4):
    - Initial backoff (0-7 BUs)
    - Subsequently doubling backoff range



Backoff comparison

- Improvement of Goodput (802.15.4 over TinyOS) over static routes:

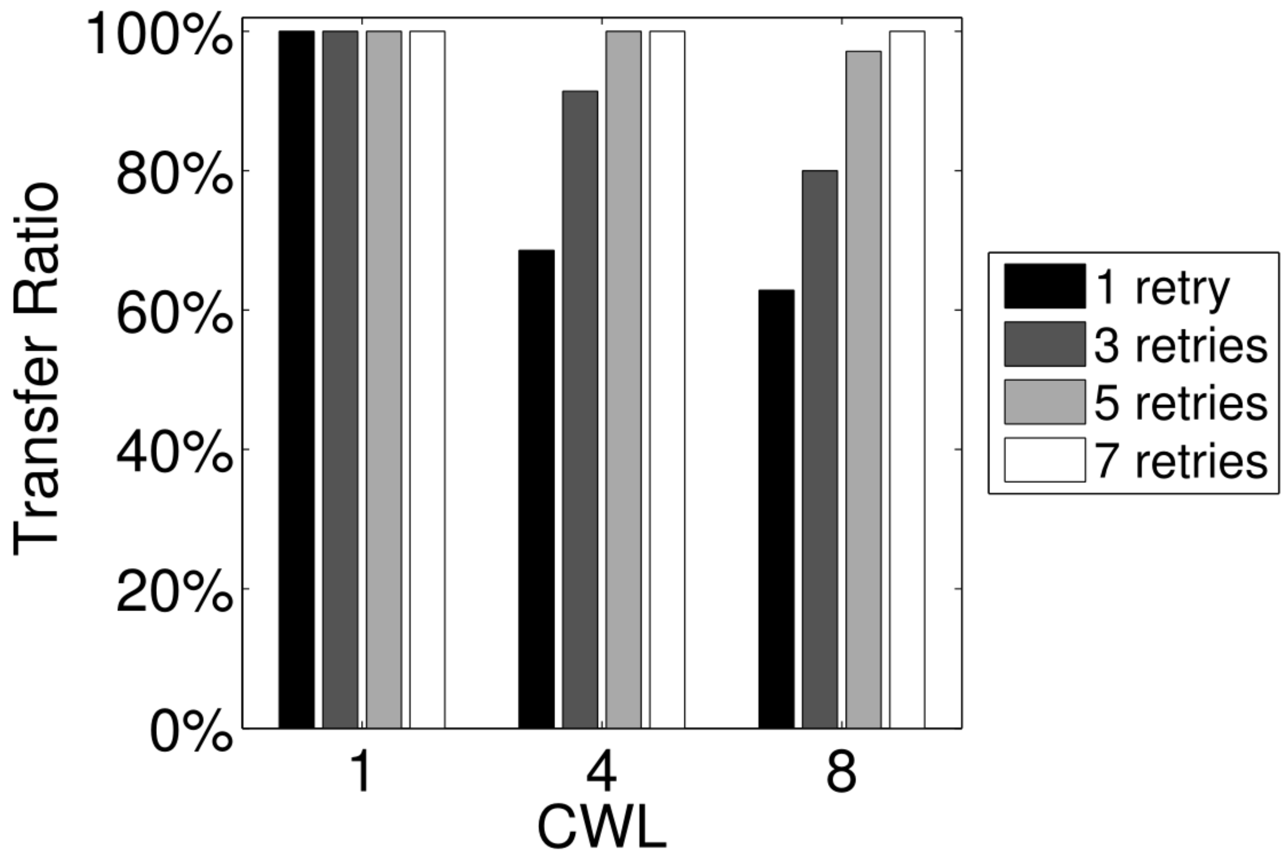


(a) CWL=1 (b) CWL=4 (c) CWL=8

MAC Layer - retries

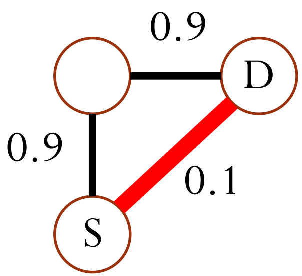
- Maximum Number of MAC layer retries:
  - Default number of retries (802.15.4): 3
  - We investigate alternative values of 1, 5, and 7 for static scenarios
- Results show that increasing the number of retries in average delivers a higher end-to-end goodput and a higher transfer ratio.
- Forwarding queues may fill more easily and end-to-end delay may increase though.

MAC retries – transfer ratio

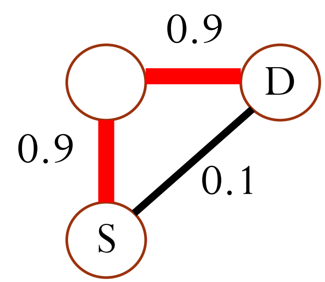


NWK - Metric

- Two routing metrics for nst-AODV are compared:
  - Hop Count metric

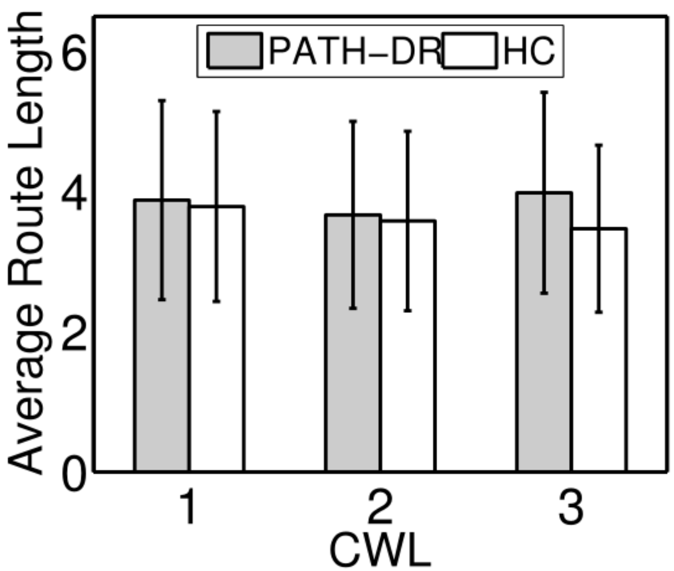


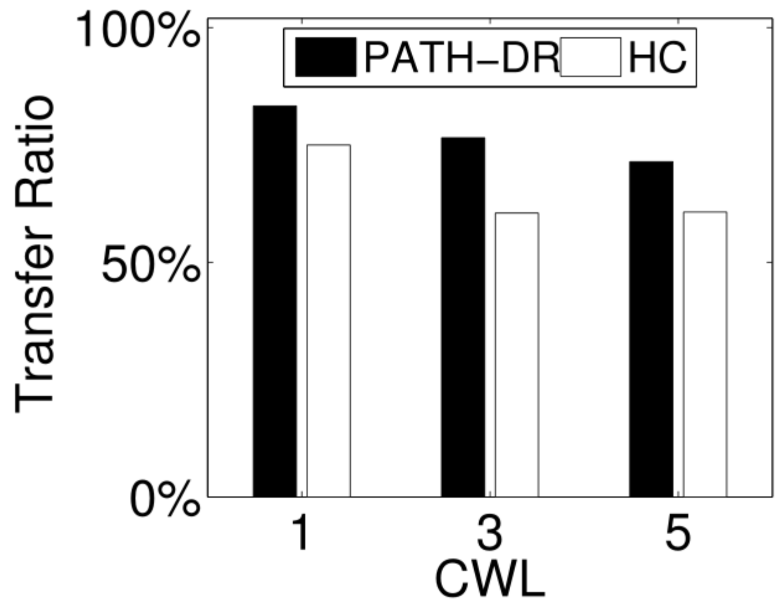
  - Path Delivery Ratio (Path – DR)



- Comparing the two metrics in dynamic scenarios (30 randomly chosen pairs of nodes, nst-AODV enabled in the whole grid).

NWK Metric - results





Transport Layer – RTO algorithms

- Compare three different algorithms:
  - Static: Random RTO from a static interval (2s-3s).
  - Semi Dynamic: Calculate Round Trip Time (RTT) once during session establishment and use a multiple of it as RTO (RTO = 4*RTT).
  - Full Dynamic/RFC6298: Calculate RTO based on SRTT, RTTVAR, etc. (taken from Karn's algorithm).

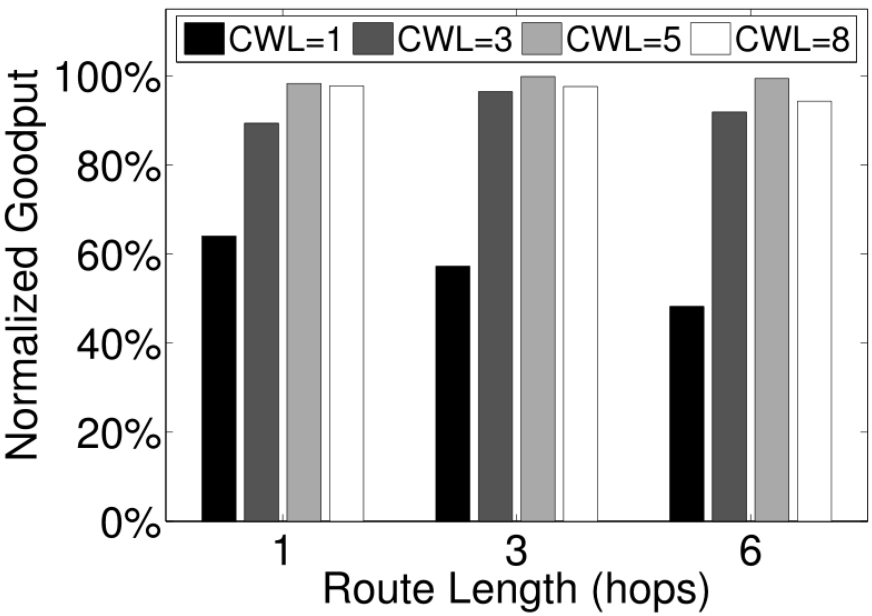
RTO algorithms - results

- The static and semi-dynamic RTO calculations deliver a worse performance than the calculation taken from the RFC in terms of goodput.
- The RTO calculation according to RFC6298 adapts well to the changing conditions of ongoing transmissions.
- More memory needs to be spent to mantain state information for a full dynamic RTO.

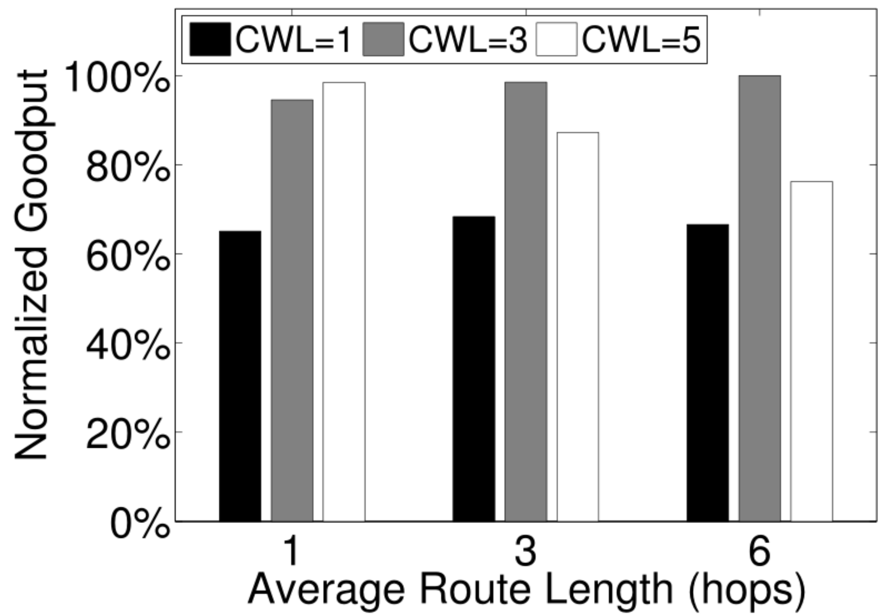
Transport Layer – CWL

- Defining a congestion window limit for TCP is important:
  - Setting the limit too low or too high may decrease performance.
  - We want to observe if there is an optimal value depending on the number of hops. In the ideal case, for single end-to-end transmissions the limiting factor is the spatial reuse.
- Different congestion window limits have been tested in static and dynamic scenarios:
  - One goal is to find a factor *s* that indicates the spatial reuse.
  - Another goal is to show that dynamically limiting the congestion window improves performance in terms of goodput.

CWL - results



(a) Static scenarios



(b) Dynamic scenarios

Conclusions and future work

- Experiments carried out in a real indoor testbed allow an realistic observation of network performance.
- Results show that choosing default parameters may not deliver optimal performance and that synergetic cross-layer effects need to be taken into account, as benefits or drawbacks.
- There is room to improve the performance by adapting mechanisms and parameters.
- Further evaluations with multiple, simultaneous flows will be carried out in extended dynamic scenarios with different use cases, as well as an in-depth analysis of potential cross-layer improvements.

Thank you!

Questions?