Congestion Control for CoAP Cloud Services

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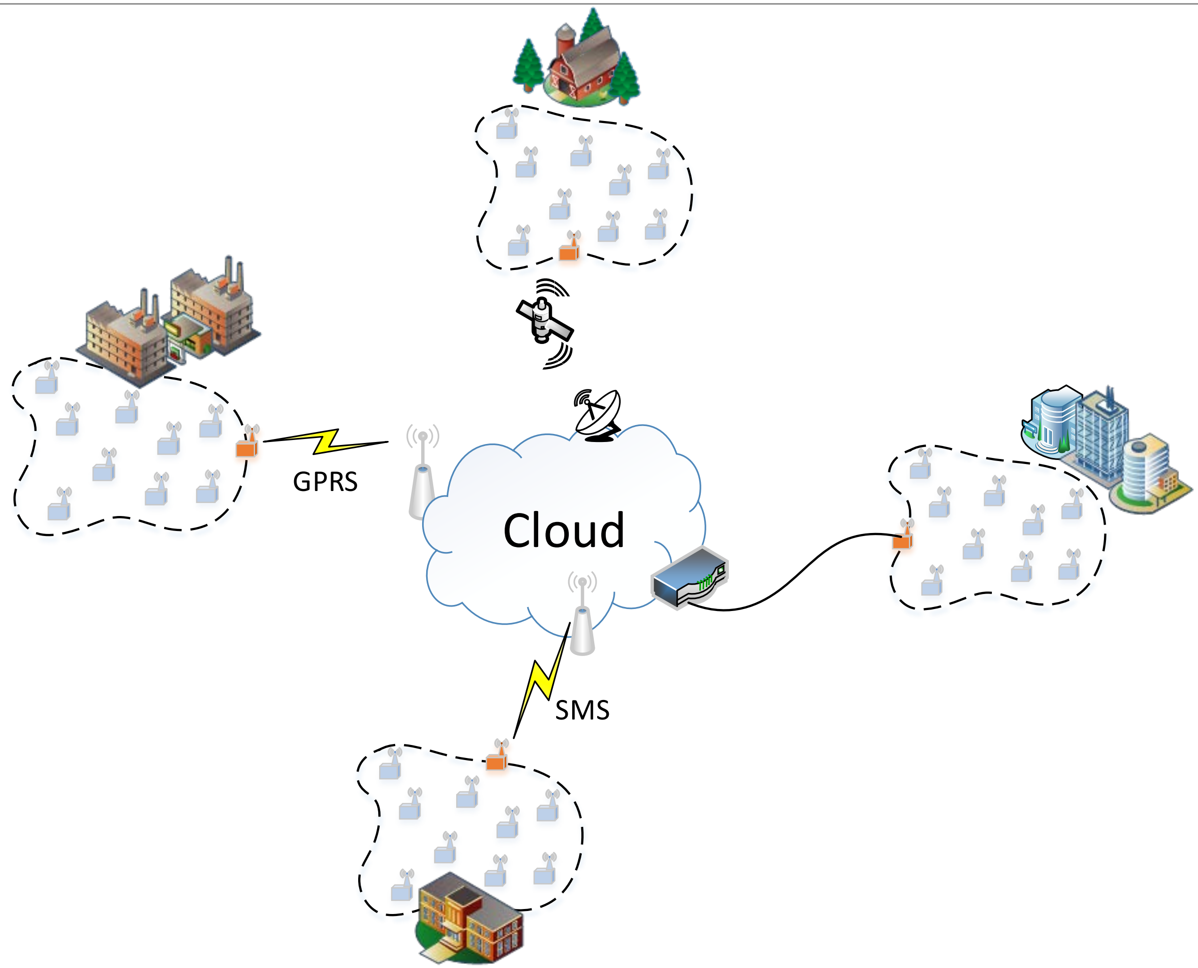
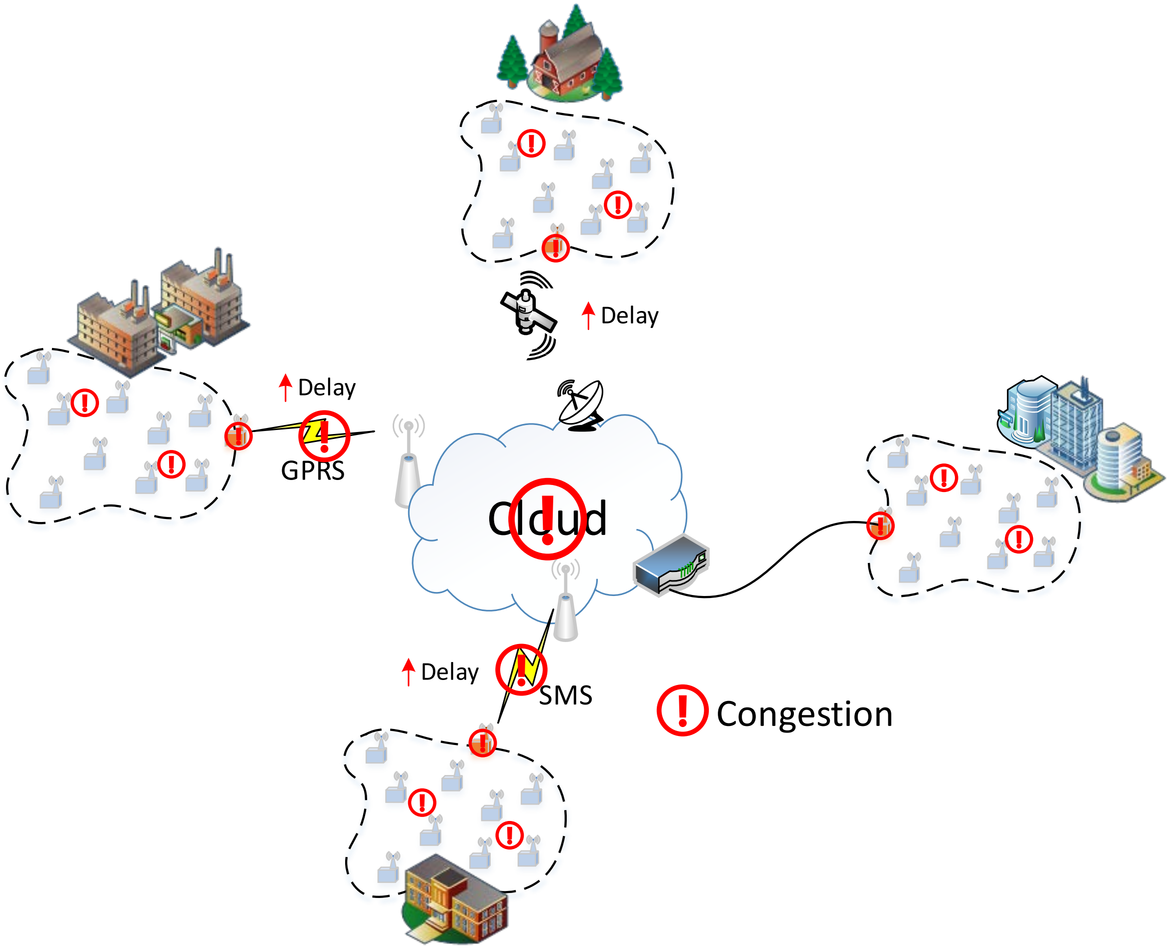
CoAP Communications



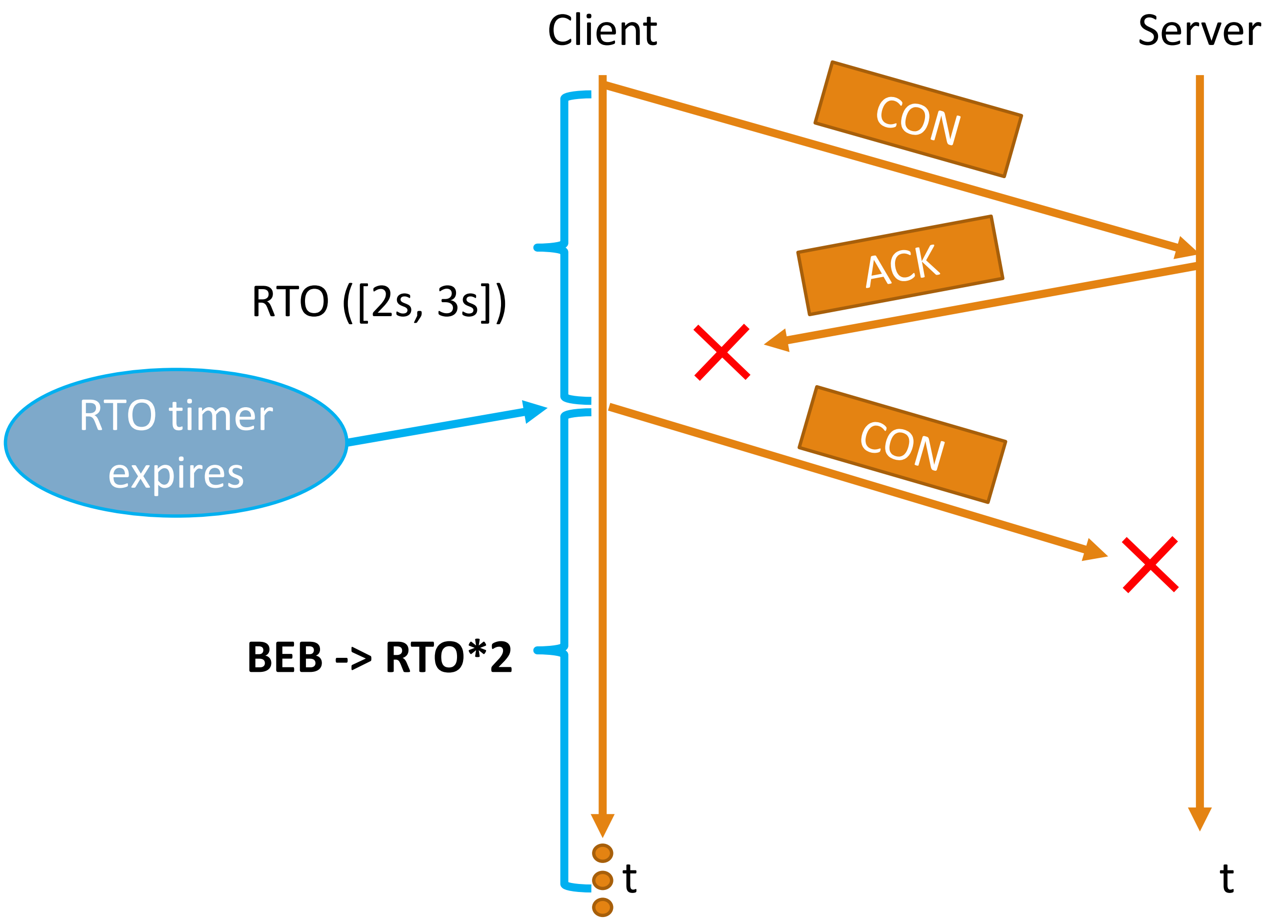
Dealing with Congestion



Introduction

- CoAP, as an Internet protocol, needs to apply congestion control, mainly to keep the backbone network stable. Thus, the CoAP specification defines a conservative default congestion control (CC) mechanism.
- To achieve a better quality of service, the IETF is designing an advanced CC mechanism for CoAP called CoCoA. We implement CoCoA and carry out performance evaluations CoCoA for communications between the Cloud and networks of constrained devices.
- First results show that CoCoA is able to better utilize the network capacity and benefits the performance.

CoAP Default Congestion Control



Advanced CC for CoAP: CoCoA (1)

- Premiss: Use Round-Trip Time (RTT) information of a **CoAP exchange (CON-ACK)** to calculate an adaptive RTO like TCP does (**RFC 6298**)
- CoCoA runs two RTO estimators:
  - **Strong estimator**: Uses ACKs from packets without retransmission.
  - **Weak estimator**: Uses ACKs from packets with retransmissions.
- Strong estimator provides an update:
  - $RTO_{overall} = 0.5 * RTO_{overall} + 0.5 * RTO_{strong}$
- Weak estimator provides an update:
  - $RTO_{overall} = 0.25 * RTO_{overall} + 0.75 * RTO_{weak}$

Advanced CC for CoAP: CoCoA (2)

- „Blind RTO“ rule: If NSTART > 1 and no RTO estimation is available

  $RTO_{init} = 2\ s\ * 2^{ACT}$, where *ACT is* # of ongoing exchanges.

- Variable Backoff Factor (VBF)
  - Avoid exchanges with large initial RTOs to take very long
  - Avoid exchanges with short initial RTOs to retransmit too fast

$$\mathrm{VBF}(\mathrm{RTO}_{init}) = \begin{cases} 3, & \mathrm{RTO}_{init} < 1s \\ 2, & 1 <= \mathrm{RTO}_{init} <= 3s \\ 1.3, & \mathrm{RTO}_{init} > 3s \end{cases}$$

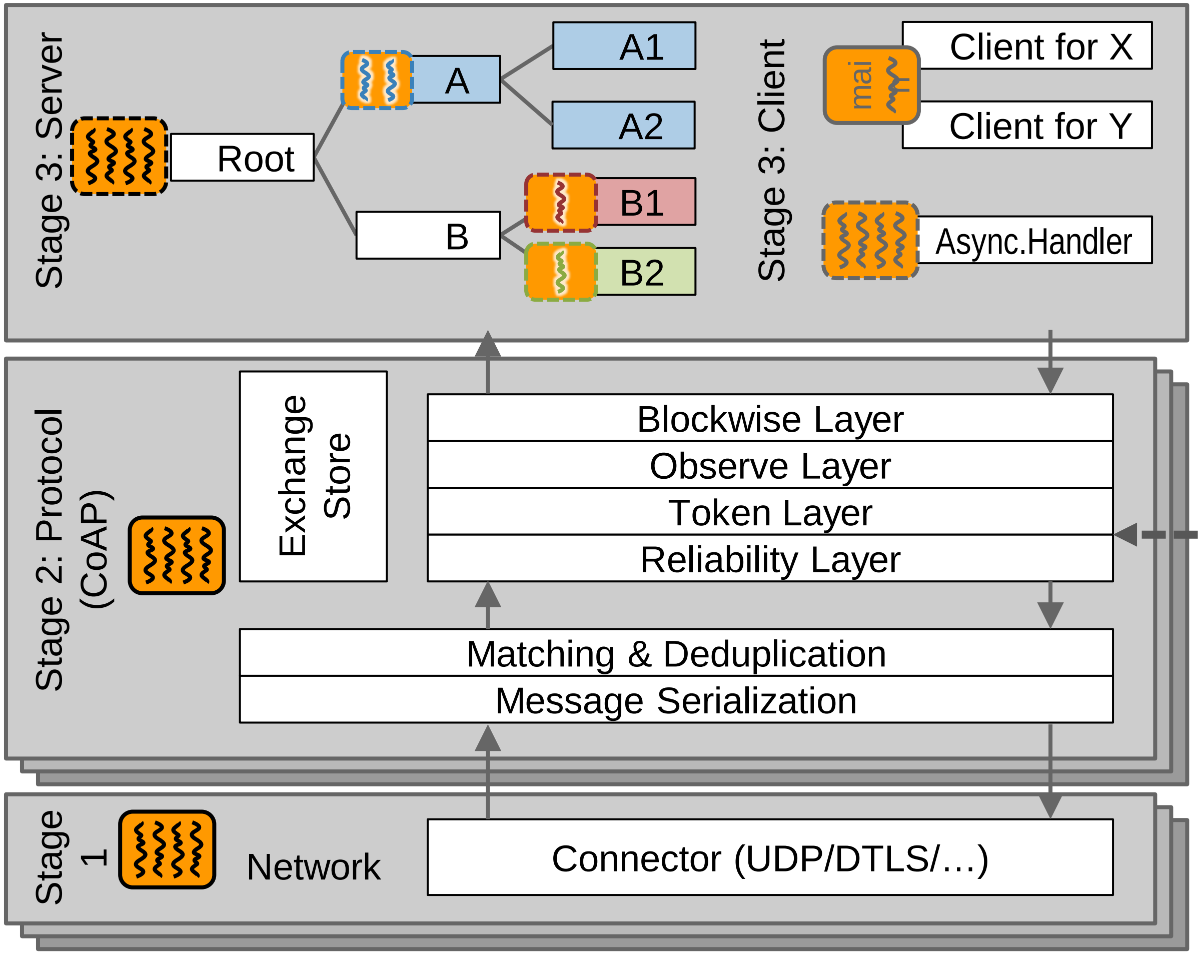
- RTO aging for small but old RTO values ($RTO_{overall}$< 1 s)

  $RTO_{overall} = RTO_{overall} * 16$

CoAP Implementation in Contiki OS: Erbium (Er)

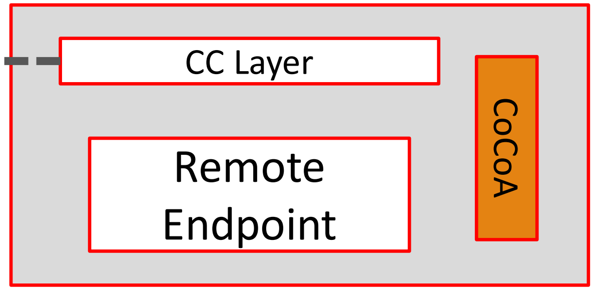
IETF communication protocol stack	Contiki implementation
CoAP	Erbium CoAP
UDP	UDP (uIPv6)
IPv6 / RPL	uIPv6 / Contiki RPL
6LoWPAN	SICSlowpan
MAC	Contiki CSMA + NullRDC
PHY	IEEE 802.15.4 PHY

CoAP Implementation for Java: Californium (Cf)



CoCoA

- Adds `RemoteEndpoint`
- Adds optional CC Layer

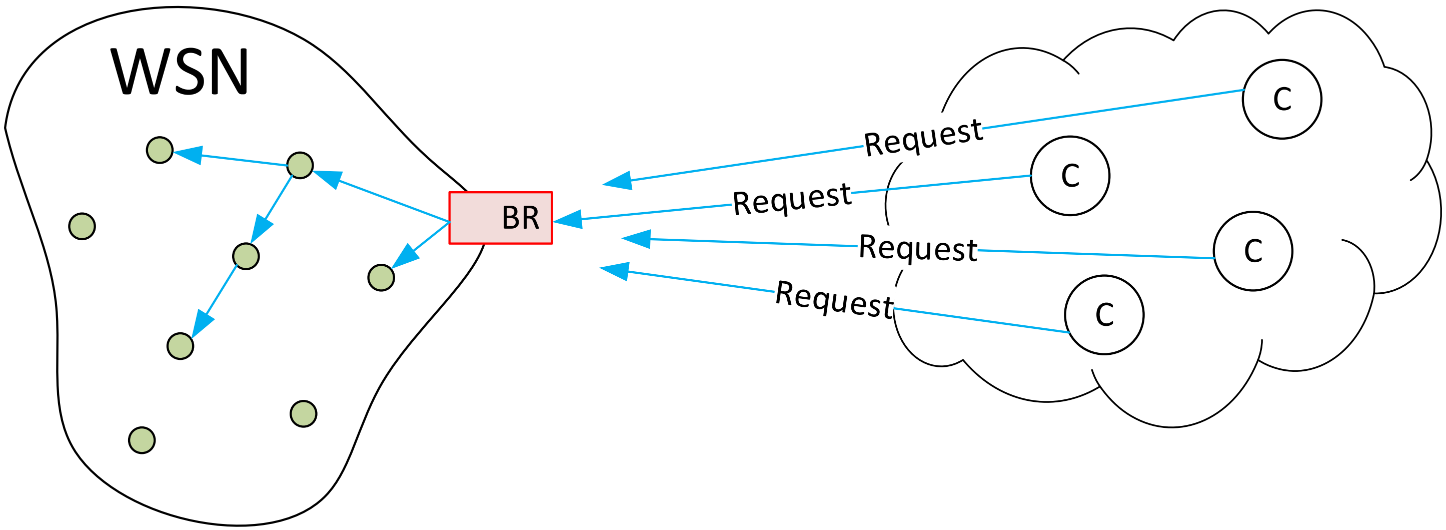


Evaluation Scenarios

- Four CC algorithms for **reliable** CoAP communication:
  - Default CoAP CC: [2 s, 3 s], BEB.
  - „Aggressive“ Default CoAP CC: [1 s, 1.5 s], BEB (CoAP$_B$).
  - CoCoA: Strong + weak RTO estimators, VBF, RTO aging, NSTART=1.
  - CoCoA$_4$: Stromg + weak RTO estimators, VBF, RTO aging, NSTART=4.
- Three use cases are evaluated:
  - 1-to-1 Baseline scenario
  - Many-to-many scenario
  - Cross traffic burst scenario

Evaluation Setup: Use Case

- WSN of constrained devices runs CoAP servers that offer resources
- CoAP clients in the cloud access the resources offered by the servers

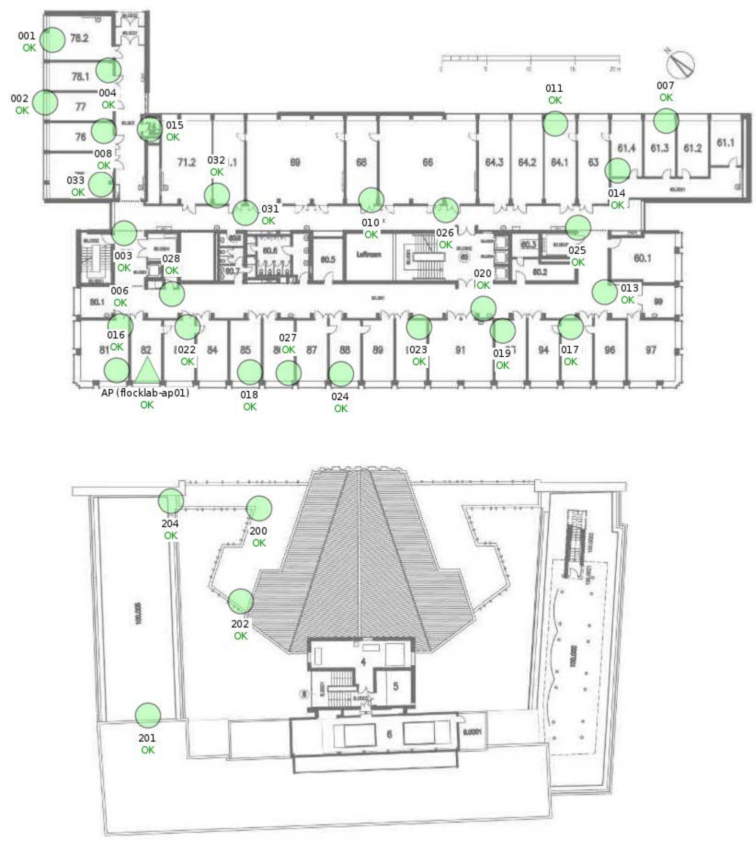


Testbed with
CoAP Servers

CoAP Clients in
the Cloud

Experimental Setup: FlockLab

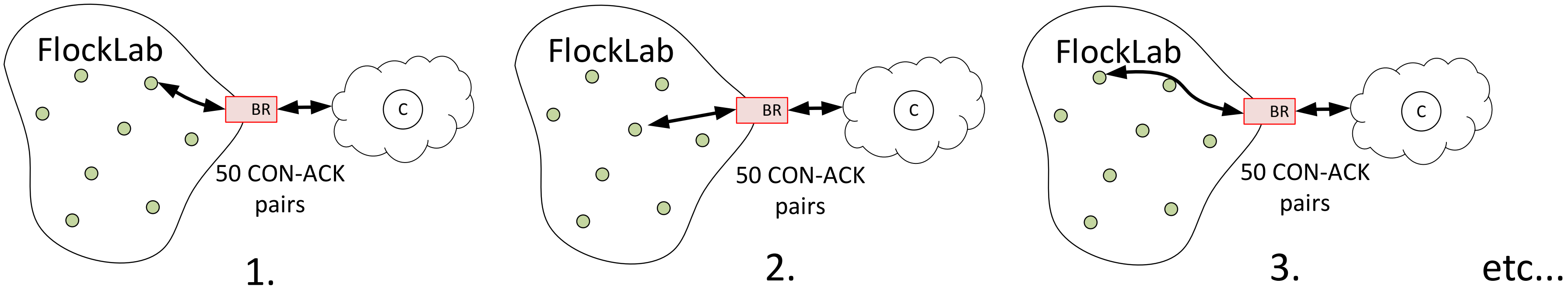
- The **FlockLab** testbed is composed of 30 Tmote Sky motes
  - 1 RPL border router
  - 29 CoAP servers (Erbium CoAP)
- The RPL border router acts as gateway between the WSN and the Cloud
- Two operational modes for the radio:
  - No RDC -> Radio always ON
  - ContikiMAC -> Radio Duty Cycling



IEEE 802.15.4 radio
10 kB RAM
48 kB ROM
MPS430 MCU

1-to-1 Baseline Scenario

- A single CoAP client on the PC exchanges 50 CON-ACK pairs with a single CoAP server in the FlockLab testbed.
- This procedure is repeated for all CoAP servers in the testbed, one after another.
- Throughput, average exchange duration and average number of retries are measured.



1-to-1 Baseline Scenario Results

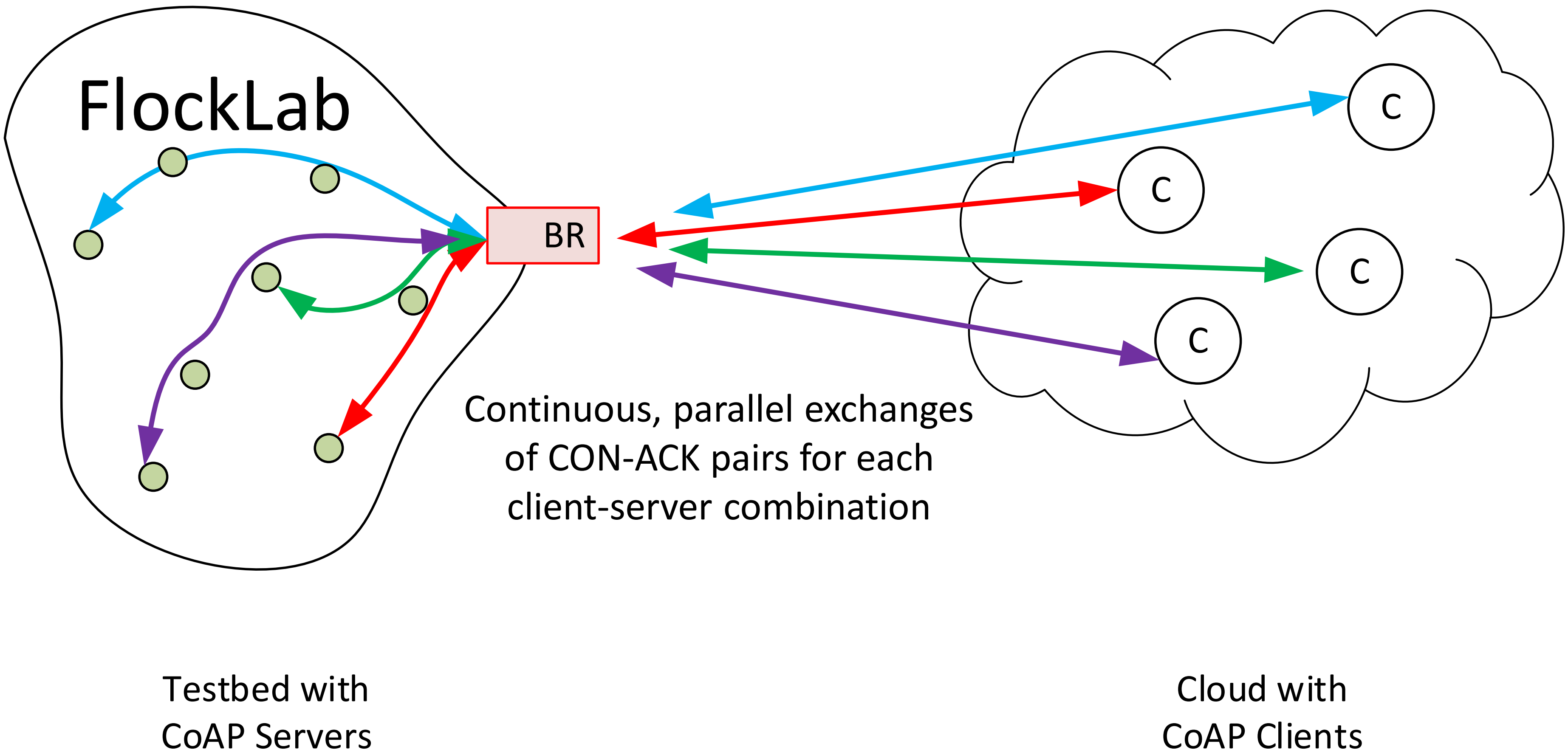
No RDC

Config	Throughput (req./s)	Exch. duration	# of retries
CoAP	0.67	1.49 s	0.40
CoAP_B	0.88	1.13 s	0.52
CoCoA	1.18	0.84 s	**0.38**
CoCoA_4	**1.42**	**0.70** s	0.56

ContikiMAC

Config	Throughput (req./s)	Exch. duration	# of retries
CoAP	0.56	1.76 s	0.21
CoAP_B	0.79	1.26 s	0.35
CoCoA	0.89	1.12 s	**0.07**
CoCoA_4	**1.18**	**0.84 s**	0.35

Many-to-many Scenario



Many-to-many Scenario Results (1)

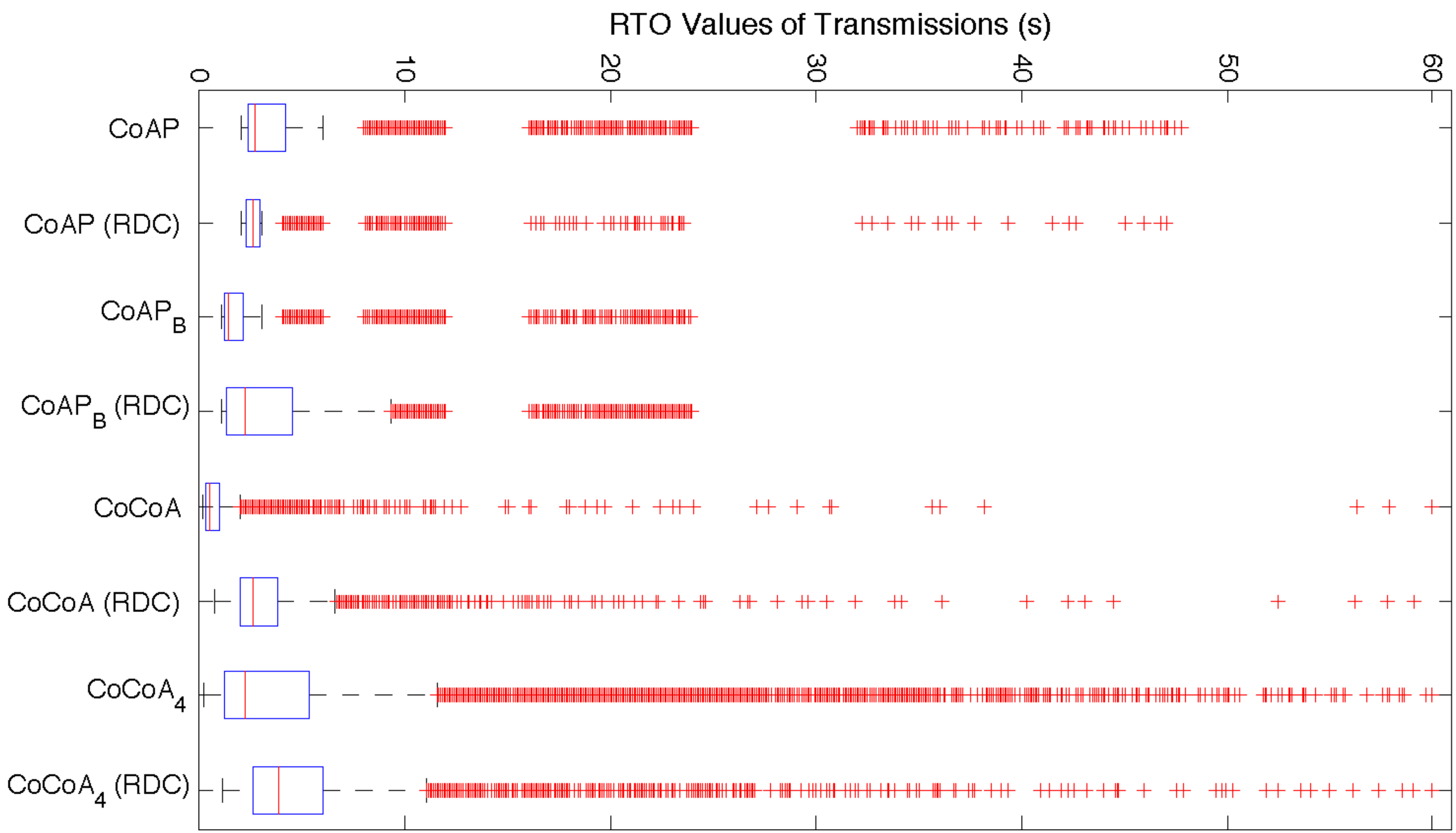
No RDC

Config	Throughput (req./s)	Exch. duration	# of retries
CoAP	4.23	2.32 s	**0.28**
$CoAP_B$	4.05	2.15 s	1.08
CoCoA	**5.34**	1.94 s	0.43
$CoCoA_4$	4.59	**1.65** s	0.67

ContikiMAC

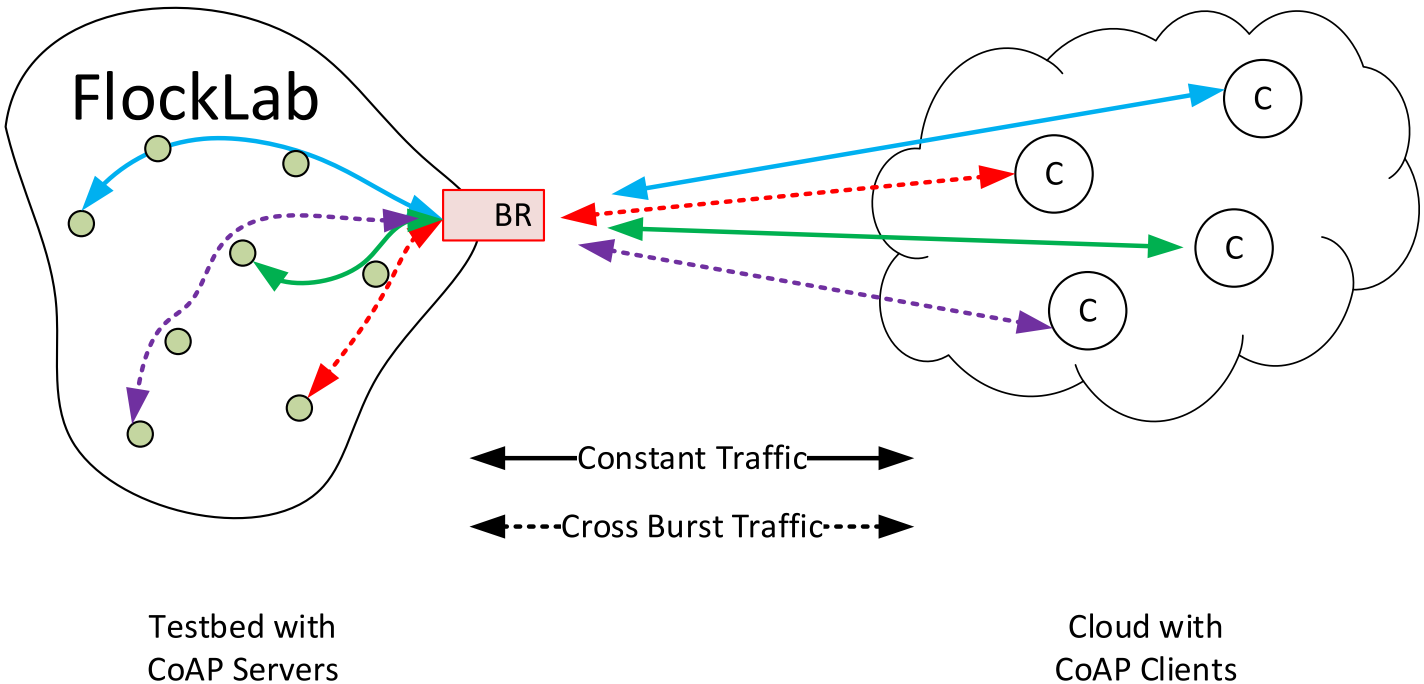
Config	Throughput (req./s)	Exch. duration	# of retries
CoAP	1.60	5.72 s	1.81
$CoAP_B$	1.45	6.06 s	2.33
CoCoA	1.79	**4.16** s	**1.69**
$CoCoA_4$	**1.90**	5.12 s	2.16

Many-to-many Scenario Results (2)

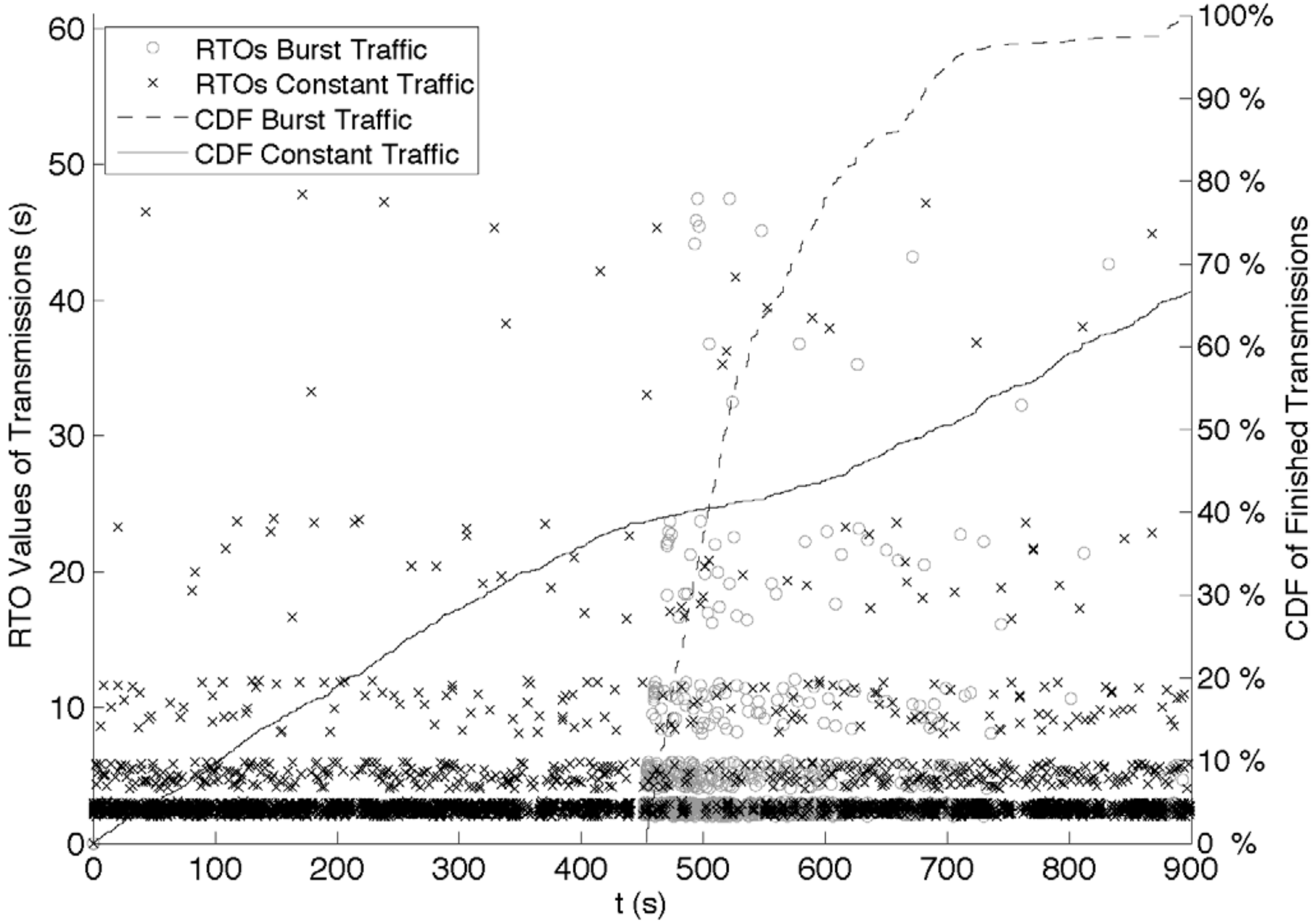


Cross Traffic Burst Scenario

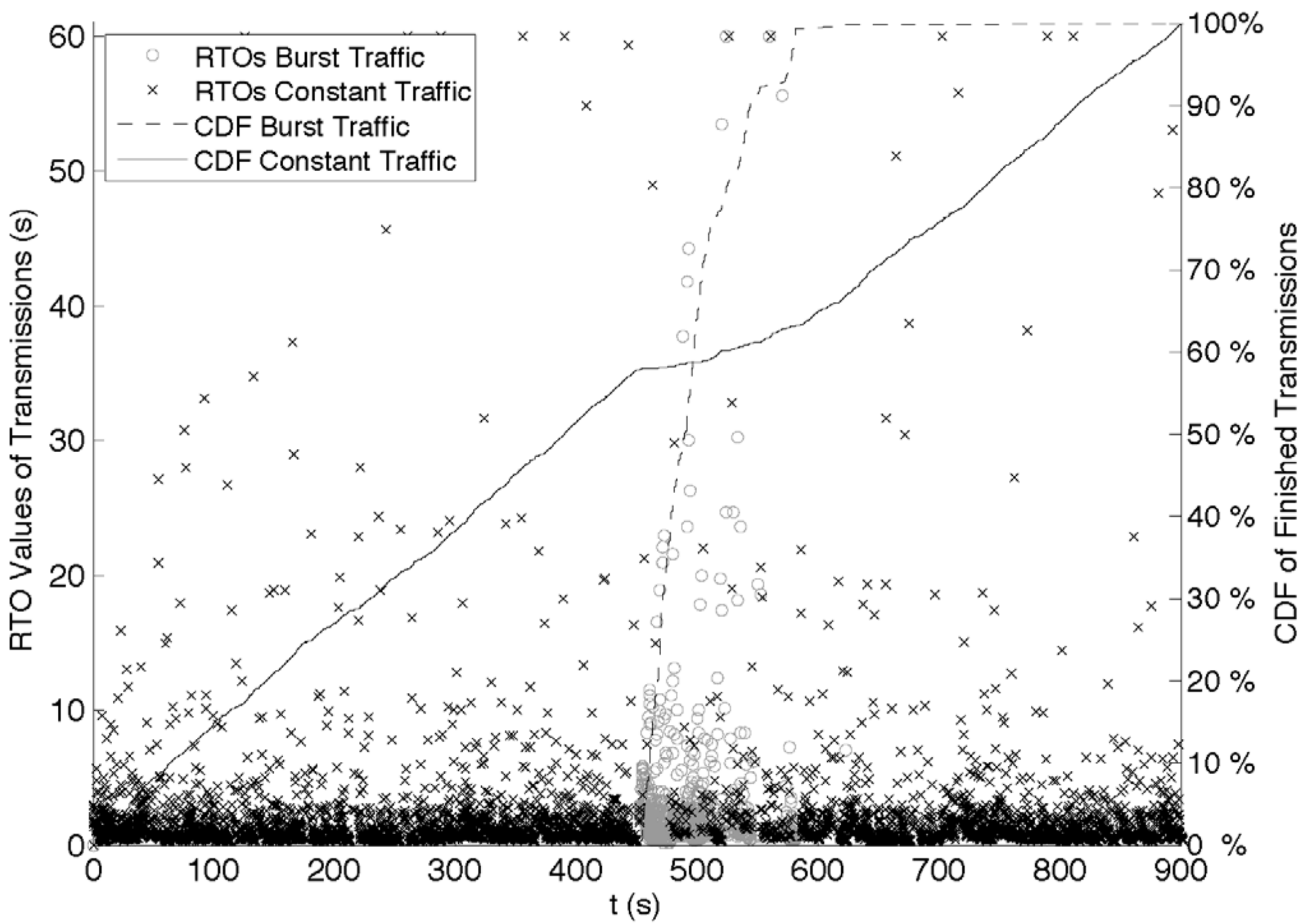
- 4 CoAP clients exchange continuously CON-ACK pairs with 4 CoAP servers. After a certain time, a burst of traffic is generated in form of 50 CON-ACK pairs, exchanged with each of the remaining CoAP servers.



Cross Traffic Burst Scenario Results: CoAP



Cross Traffic Burst Scenario Results: CoCoA



Conclusions

- CoCoA has been implemented as optional CC Layer for the Cf framework.
- Experiments that involve communications between the Cloud and a WSN of constrained devices have been carried out to compare the performance of default CoAP CC mechanisms with CoCoA's mechanisms.
- CoCoA utilizes the network better than default CoAP:
  - CoCoA is able to increase the amount of requests that can be processed in parallel.
  - The time required to fulfill a task is reduced with CoCoA.
- With CoCoA, NSTART can be increased safely, even though it does not always deliver an optimal performance.

Thank you!

Questions?

Future Work

Traffic:

- Include non-confirmable messages in the traffic scenarios.
- Include observe mechanism in the evaluations.
- Include links with large delays, such as GPRS or satellite links.

Evaluation:

- Comparison of other well known RTO algorithms (Linux RTO, Peakhopper, etc.).
- Other performance metrics, like energy efficiency, should be analyzed as they are important for WSNs.

CoCoA Internet Draft:

- Feedback from the community is required, more experiments or simulations can help to improve CoCoA further.