Master's Thesis

A Resilient Transport Layer for Messaging Systems

David Fuchs

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Supervision:
Dr. Sean Rooney (IBM Research GmbH, Zurich Research Laboratory)
Prof. Dr. Gustavo Alonso (ETH Zurich, Institute for Pervasive Computing)

Outline

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MQTT Protocol

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Lightweight Publish/Subscribe protocol

- broker/client architecture
- clients subscribe to topics they are interested in
- clients publish messages on a topic
- broker forwards messages to all interested parties

Designed for many-to-many communication with easy configuration

Designed for network edge devices

- typically small devices with limited battery power, processing power
- examples: hand-held devices, temperature sensors, flow meters, power meters, ...

Usage Example

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"Black Box" in car

- records usage of car (speed, time of day, distance, ...)
- periodically sends data to insurance company
- data transmission uses GPRS-link with high latency, low bandwidth
- premium is based on actual usage rather than age, ethnic group, etc

QoS Levels

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QoS 0: best effort

- used when loss of messages is tolerable

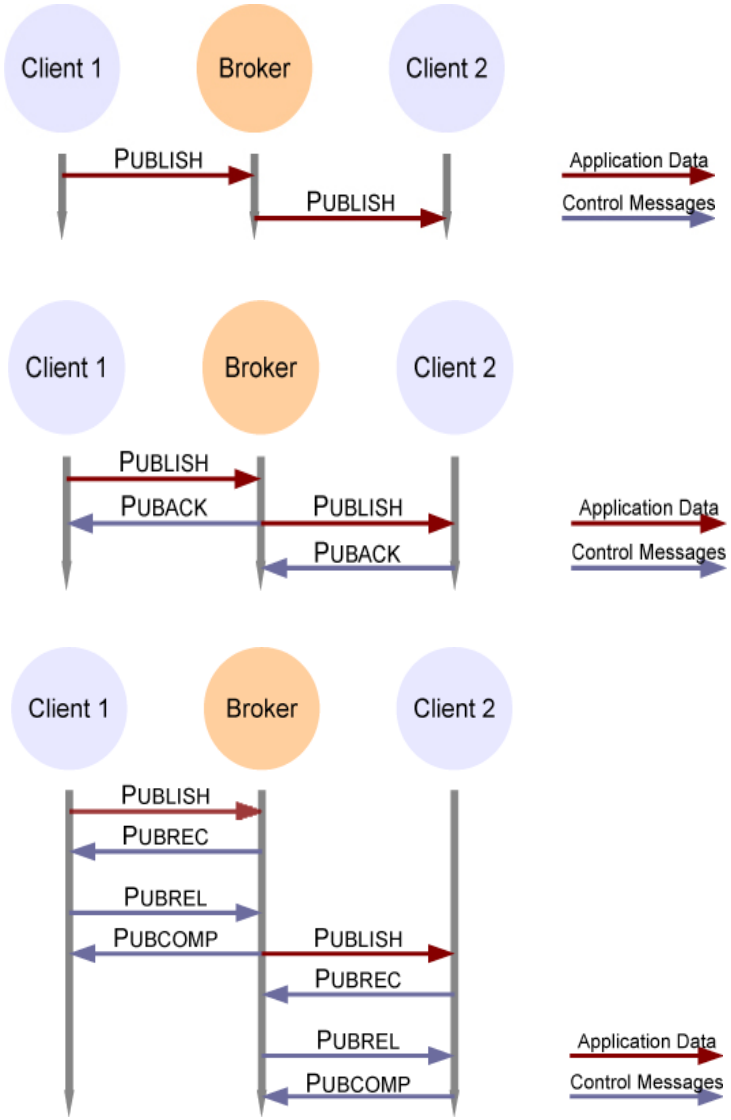
QoS 1: at-least-once

- when loss is not tolerable, but duplicates are
- seldomly used

QoS 2: exactly-once

- when no loss and no duplicates are tolerable

To add resiliency to application failures, msgs may be persisted



Motivation for Resiliency Layer

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Some applications need exactly-once semantic

- e.g., scanner in a warehouse scanning outgoing goods

But QoS 2 is “expensive”:

- requires 1.5 round trips until message gets delivered
- adds to bandwidth consumption, which is especially bad for wireless connections (power consumption)
- inefficient use of bandwidth, because delivery protocol is executed sequentially for each single message

➔ Goals of ReTCP:

- exactly-once delivery
- resilient against network failures & application failures
- less byte overhead than QoS 2
- smaller delivery latency than QoS 2
- assumptions: network connections fail; applications hang, crash,loose packets

ReTCP Overview

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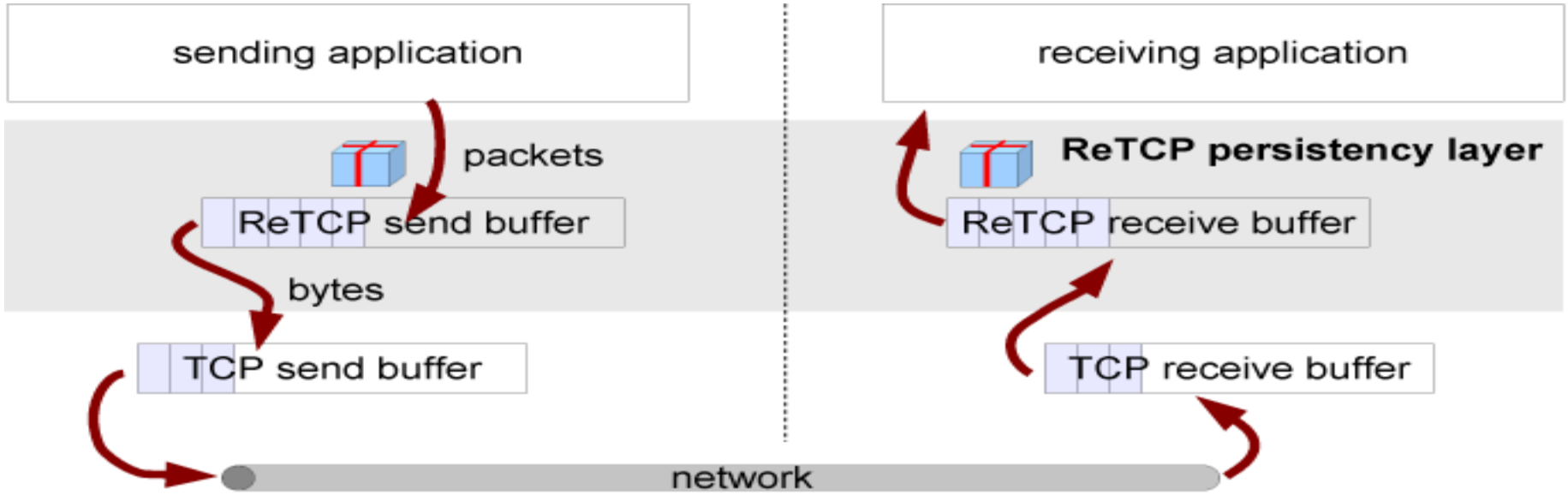

Runs on top of TCP

- TCP connections may break, but when connected, assure in-order delivery, flow control, congestion control, error detection

Packet-oriented

- rather than byte-stream like TCP

Buffers are stored persistently on disk

ReTCP Design

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ReTCP “session”:

- can encompass several TCP connections
- client is responsible for reconnecting after crash or network failure
- identified by a connection id; client sends client id and connection id in connection request

ReTCP packets are sent with sequence numbers

- to assure in-order delivery when sessions are aborted and resumed...
- ...and to detect packets that the receiving application lost
- cumulative Ack scheme is used
- RTO timers are used, as in TCP

"TCP-over-TCP" Problems

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"TCP Meltdown" effect

- happens when upper layer starts retransmitting packets faster than lower layer
- solution: when RTO timer expires, only resend packet when $RTO_{ReTCP} > RTO_{TCP}$. Otherwise, backoff the timer w/o retransmission.

Effects of packet size

- packet sizes span many orders of magnitude (MQTT: 1B...265MB)
- Ack might not be received simply because it is queued behind a large packet that takes long to send
- solution: never resend a packet while data is being read from the incoming byte stream

How to calculate the RTO based on packet size?

RTO Calculation

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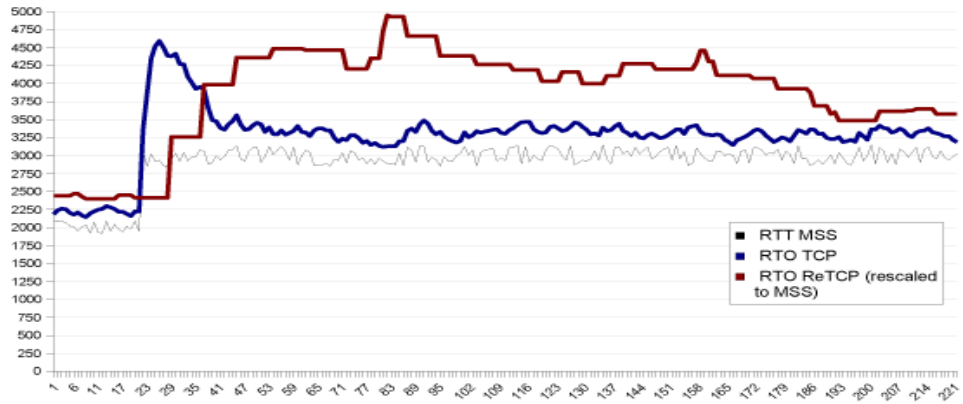
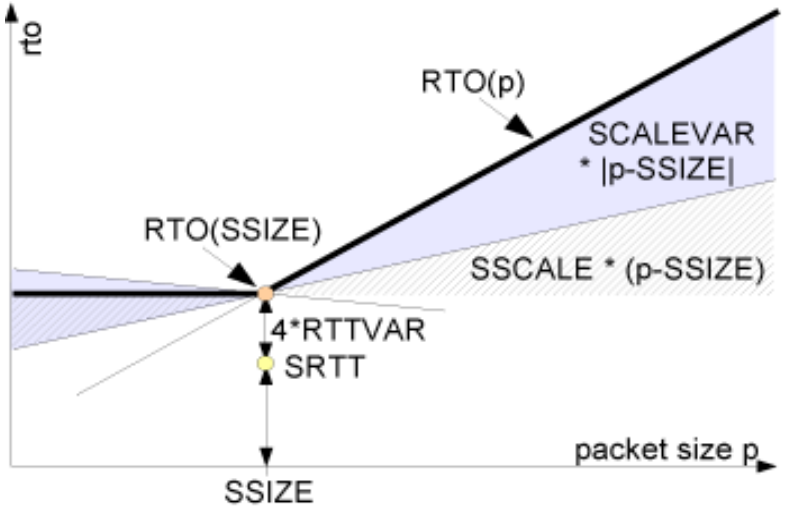
Assumption: RTT rises linearly with packet size, with an initial fixed latency.

- TCP bases its RTO an averaged past RTTs and their variance
- instead of calculating a scalar value as TCP does, the ReTCP RTO algorithm works in 2 dimensions (RTO time, packet size)
- position and slope of the averaged RTT line are updated when new (packet size, RTT time) measurements are available
- calculated RTO is based on averaged RTT line, variance of position, and variance of slope

Simulation shows it works





Implementation

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Implementation is provided for Java-based MQTT protocol stack

- to handle persistent storing of objects, IBM's `ObjectManager` Java library is used
- the `ObjectManager` offers transactions with the typical ACID properties of a database, but is designed to be light-weight and much faster than most DBMS

Information pertinent to TCP's connection state is read from the `/proc` pseudo file system

- information about buffer states, RTO and much more can be found in `/proc/net/tcp` and `/proc/net/tcp6`
- works for Linux-based OSes only

Performance Results

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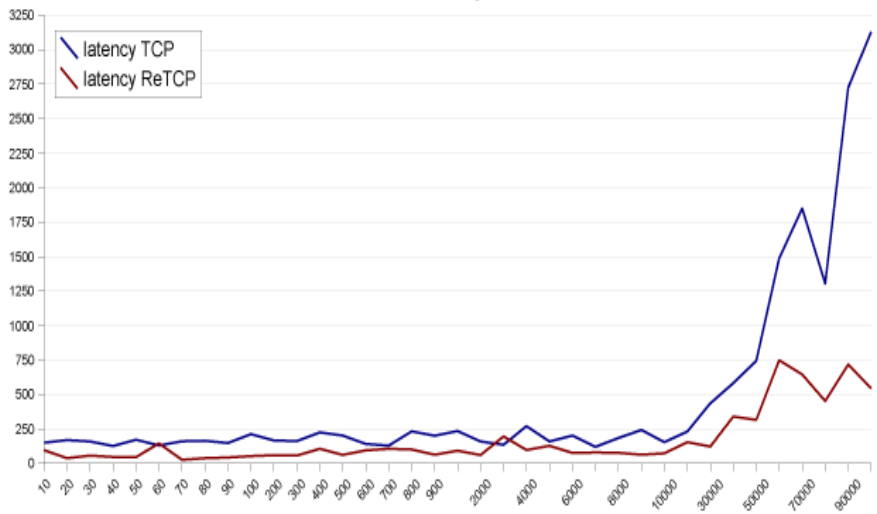
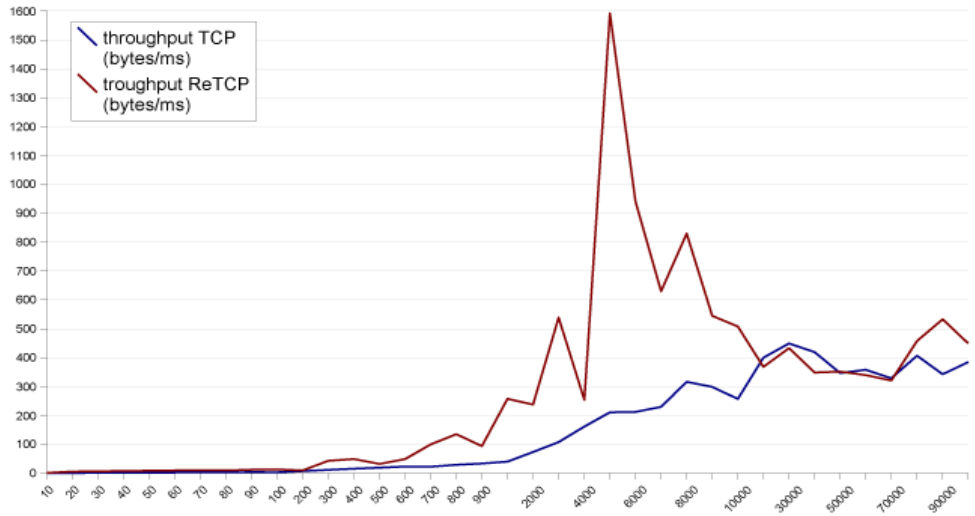
Performance is compared to existing QoS 2 impl.

- various network conditions emulated with NIST Net

Results indicate better throughput and delivery latency

- graphs show latency, throughput for network with link delay of 1.5 ms, and highly correlated loss probability of 10%





Thanx for your Attention!

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Useful resources:

- MQTT protocol information and specification:
  http://mqtt.org/
- NIST Net network emulator:
  http://www-x.antd.nist.gov/nistnet/
- this presentation, master's thesis report:
  http://n.ethz.ch/~fuchsd/ReTCP/