Embedded Actors — Towards Distributed Programming in the IoT

Raphael Hiesgen, Dominik Charousset, Thomas C. Schmidt

HAW Hamburg

raphael.hiesgen@haw-hamburg.de

September 2014, ICCE-Berlin

Hochschule für Angewandte Wissenschaften Hamburg

Hamburg University of Applied Sciences

Agenda

1. The Internet of Things (IoT)
2. The Actor Model
3. Communication in the IoT
4. Messaging Architecture
5. Evaluation
6. Conclusion & Outlook

The Internet of Things (IoT)

- Characteristics
  - Cooperatively process complex duties
  - Dependent on machine-to-machine communication
  - Connected to the Internet
  - Implemented with networking standards
  - Often constrained environment
- Developing for the IoT
  - Fall back to low-level programming
  - Hand-crafted network code
  - Barely portable code

$\Rightarrow$ Raise the level of abstraction through the actor model

Agenda

The Actor Model

- Isolated, concurrent software entities: actors
- Network-transparent message passing
- Divide & conquer via "spawn"
- Strong, hierarchical failure model
- Re-deployment at runtime

Limitations

- Actors not yet established in the native programming domain
  - Need to broaden range of applications
  - Deploy actors in performance-critical systems

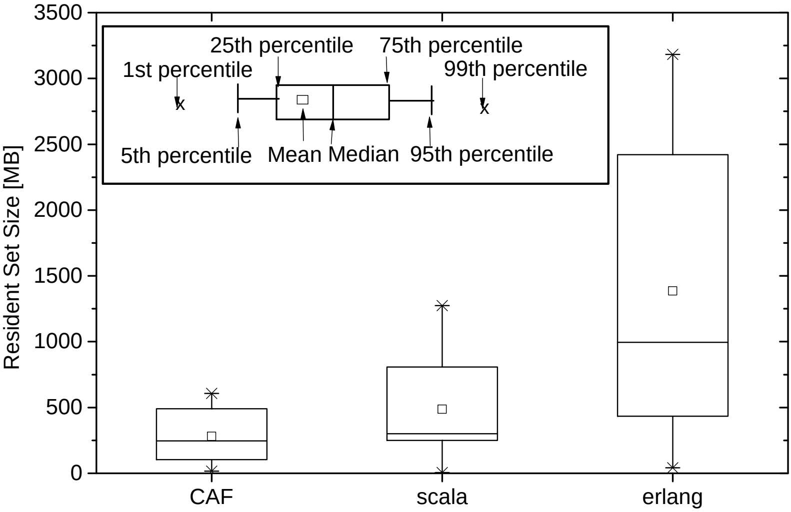
- Actors not available for embedded systems
  - Why not model the "Internet of Things" as network of actors?
  - HW platform should not dictate programming model

The C++ Actor Framework

- The C++ Actor Framework (`CAF`) is an `C++11` actor system
- Previously named `libcppa`
- Efficient program execution
  - Low memory footprint
  - Fast, lock-free mailbox implementation
- Targets both high-end and low-end computing
  - Multi-core & many-node systems
  - Embedded HW, e.g., running RIOT [1]

[1] http://www.riot-os.org

Memory Usage



Agenda

Communication in the IoT

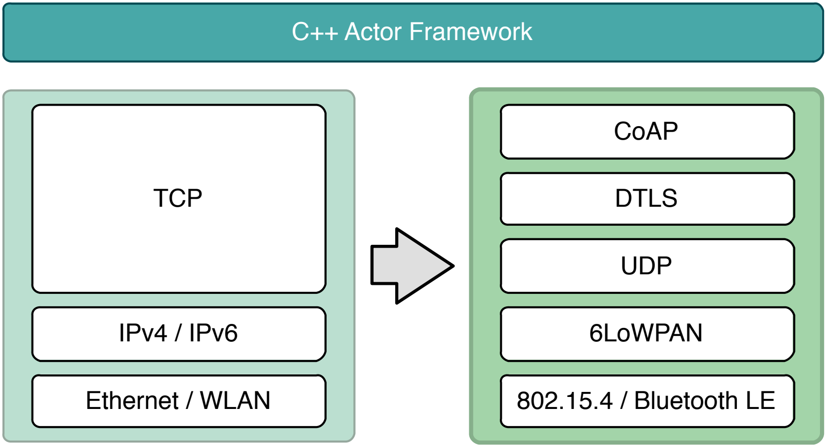
- Loosely coupled
  - Unreliable links
  - Infrastructure failure
- Challenges
  - Error propagation for non-hierarchical systems
  - Secure and authenticated connectivity
- Multiple open standards available to meet these challenges

Standards for the IoT

- Bluetooth low energy
  - Supported by all major OSs
- IEEE 802.15.4
  - WPAN for embedded devices
  - 127 bytes frame size
- IPv6 over Low-Power Wireless Personal Area Networks (6LoWPAN)
  - IPv6 compatibility
  - Header compression
- UDP / Datagram Transport Layer Security (DTLS)
  - Features of TLS with datagrams
  - Reordering, retransmission and fragmentation for the handshake
- Constrained Application Protocol (CoAP)
  - Request-response model adapted from HTTP
  - Works asynchronously over datagram protocols
  - Offers reliability through Confirmable messages (CON)

Agenda

CAF Network Stack



Messaging Architecture Between Actors

- Map CoAP messages to CAF
  - Reliability (CON) $\rightarrow$ synchronous messages
  - Unreliability (NON) $\rightarrow$ asynchronous messages
- Handle small frame sizes
  - Compress meta-information to slim down headers
  - Type-exchange & annotation introduces more state
  - Fragmentation on the application layer (CoAP block messages)
- Concept for error-propagation
  - No longer connection oriented
  - Based on asynchronous transactions (CoAP)
  - Take unreliable messages into account

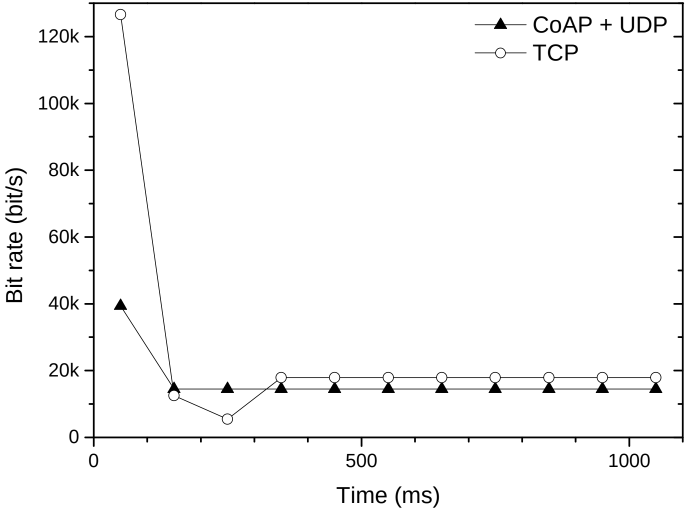
Agenda

Packet Flow Evaluation

- Proof-of-concept implementation
  - Network stack composed of Ethernet, UDP and CoAP
  - Based on libcoap [2]
- Bitrate & message count compared to TCP based impl.
- Raspberry Pi sends 10 *bytes* to a desktop PC every 100 *ms*
  - Characteristic scenario for sensor nodes
- Trace network traffic (handshakes, ACKs, messages, ...)

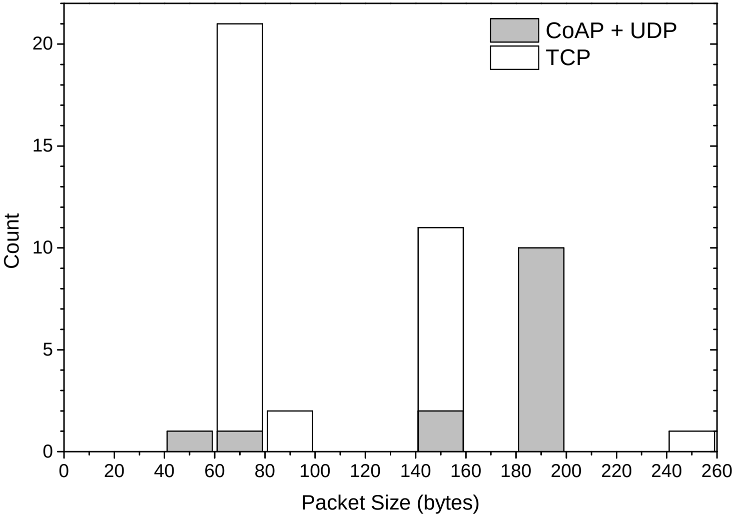
[2] http://libcoap.sourceforge.net

Packet Flow



CoAP + UDP
TCP
Bit rate (bit/s)
120k
100k
80k
60k
40k
20k
0
0
500
1000
Time (ms)

Packet Size Distribution



Agenda

Conclusion & Outlook

- Development for the IoT requires specialized knowledge
  - Network communication & synchronization
  - Port software to different hardware
- The actor model abstracts over distributed systems
- Adjusted the `CAF` network stack to the IoT
- Proof-of-concept with first measurements

- Future work
  - Concept for error-propagation
  - Additional CoAP drafts (CoCoA, block messages, ...)
  - Evaluation of packet loss, message sizes
  - Adaption to RIOT

Thank you for your attention!

Website: http://actor-framework.org

Sources: https://github.com/actor-framework

iNET working group: http://inet.cpt.haw-hamburg.de