MAC Processor Development for GNURadio

Jarriel Cook
The Johns Hopkins Applied Physics Lab
A Different Approach

Without using QP™, I don’t believe we could have delivered on our given schedule dates with the same level of quality.

Jeff Karau, Sr. Software Engineer, General Dynamics C4 Systems

Quantum Leap’s software has revolutionized not just the way we write our software, but the way we approach our design. It is intuitive, easy to implement and comes in an incredibly small package.

Chat Koster, Software Engineer, Honeywell

I used the traditional RTOS approach for about 10 years. With the real-time debug capability of QP/Spine™ and the ability to see what is going on in the logic flow, the code is very easy to debug and modify. It makes the code very modular and deterministic. You end up talking about the code, not the semantics of the software. QP™ is a great product.

Paul Walker, Software Engineer, EIM Controls, Inc.

All company names and logos mentioned herein are the trademarks of their respective owners.
About QP

• Quantum Leaps
  • Company that created the state machine software
  • Website: https://www.state-machine.com/

• QP Frameworks
  • A collection of ports that support building of event-driven applications
  • Support for C and C++, ports for Bare-Metal ARM, QT GUI, RTOS, etc.
  • Over 15 years of continuous development and 60,000 downloads a year
  • Licensed under GPLv3 or a commercial license

• QM
  • Quantum Modelling Tool
  • Model based design tool which auto-generates QEP source code

• QTools
  • QSpy is of primary interest for run-time tracing
Provides a Framework For:

• Thread-per-state-machine execution context
• Event queues
• Event based timing services
• Run-time execution tracing
• *Graphical* model-based design
CHEESY MAC provides "extension" objects

CHEESY MAC provides the BSP for POSIX targets
What is CHEESY MAC?

• CHEESY MAC is an Open Source toolkit which leverages the QP event driven design framework to enable a consistent approach to development of communication protocols

• CHEESY MAC is intended to interface with physical layer implementations to enable ease of development and maintenance in complex applications
The CHEESY MAC Toolkit
CHEESY MAC Architecture

QM Tool

Application Generator

Visual Application Model

Quantum Modeler (QM)

Code Generator

QEP Application

Proto File(s)
Supplemental Protocols
QEP Modules
QEP Support

ProtoBuf (Custom Protocols)
Librafter (Binary Protocols)
liburn
QPCPP
OSPY

Spyview (Remote Tracing)

Runtime Events

CTRL/DATA Packets
(Protobuf or Librafter)

Gr-macproc
Gr-macproc Extensions
GNURadio Flowgraph

Legend

Developer Provided
Open Source
CHEESY MAC
QEP Framework
CHEESY MAC Architecture

Control
Control in **CHEESY MAC**

**ZMQ PUB-SUB**

sockets for bi-directional data

**Tune requests**

**CCA replies**

**CCA requests**

**ZMQ REP socket for control**

**CHEESy MAC**

- Options
  - ID: transceiver_DOQPSK_minimal
  - Title: IEEE 802.15.4 DQPSK PHY
  - Generate Options: QT GUI
  - Realtime Scheduling: On

- Variable
  - ID: samp_rate
  - Value: 4M

- QT GUI Range
  - ID: gain
  - Default Value: 30
  - Start: 1
  - Step: 100

- QT GUI Range
  - ID: freq
  - Default Value: 11
  - Start: 11
  - Step: 28
  - Step: 1

**PLME**

- Binding: tcp://tmp/plme-0

**UHD: USRP Source**

- Device Arguments: type=b200
- Samp Rate (bps): 4M
- Ch0: Center Freq (Hz): 11
- Ch0: Gain Value: 30
- Ch0: Antenna: RX2

**PD**

- Publish Binding: ipc:///pd-out
- Subscribe Binding: ipc:///pd-in

**IEEE802.15.4 DQPSK PHY**

**CCM**

- Binding: ipc:///tmp/plme-0

**QT GUI Frequency Sink**

- Name: FFT Plot
- FFT Size: 1.024
- Center Frequency (Hz): 0
- Bandwidth (Hz): 4M

**UHD: USRP Sink**

- Device Arguments: type=b200
- Samp Rate (bps): 4M
- Ch0: Center Freq (Hz): 11
- Ch0: Gain Value: 30
- Ch0: Antenna: TX/RX
- TSB tag name:
CHEESY MAC Architecture

Hierarchical State Machines

Control
Hierarchical State Machines in CHEESY MAC

Synchronous ZMQ REQ Events for control

Asynchronous ZMQ SUB Events for data

GNURadio Modem
CHEESY MAC Architecture

Hierarchical State Machines

Encapsulation

Control
Encapsulation in CHEESY MAC

Protobuf Encapsulation

<table>
<thead>
<tr>
<th>Length</th>
<th>Tag</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0a</td>
<td>Martin</td>
</tr>
<tr>
<td>10</td>
<td>b9</td>
<td>0a</td>
</tr>
<tr>
<td>11</td>
<td>0b</td>
<td>daydreaming</td>
</tr>
<tr>
<td>11</td>
<td>07</td>
<td>hacking</td>
</tr>
</tbody>
</table>

Total: 33 bytes

Binary Encapsulation Using Libcrafter

GNURadio Modem
CHEESY MAC Architecture

Hierarchical State Machines

Encapsulation

Control
Extensions in CHEESY MAC

CHEESY MAC App

- Import existing QM packages
  - ZMQ uses an import package
- Create custom packages for extended functionality
  - Implement custom state machines in qm_modules
  - Import package into QM project
  - CHEES will automatically build and link new functionality

Interfaces | Protocols | Functions
---|---|---
MQTT | ZMQ | 6LowPAN
802.15.4 | CSMA
CHEESY MAC Architecture

Hierarchical State Machines

Encapsulation

Control

Extensions

SPY

Legend

Developer Provided
Open Source
CHEESY MAC
QEP Framework
Spy in **CHEESY MAC**

**CHEESEY MAC App**

**Runtime Events**

**Spyview**

**Sequence Diagrams**
Source Code

- Public Release Review Underway

- Will post to: https://github.com/cheesymactoolkit

- GPLv3 license