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Using MQtt as Heterogeneous Distributed Message Infrastructure for WEST CODAC

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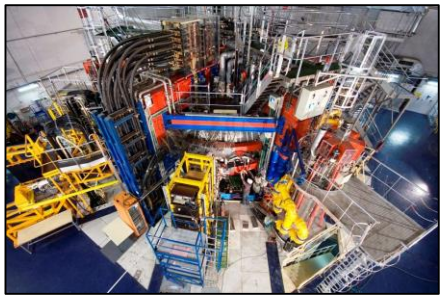
13TH TECHNICAL MEETING ON PLASMA CONTROL SYSTEMS, DATA MANAGEMENT AND REMOTE EXPERIMENTS IN FUSION RESEARCH

5TH TO 8TH JULY 2021, CULHAM, UNITED KINGDOM

Since 2013 => **re-factoring of WEST CODAC source code**.



Tokamak WEST

Goals :

- Modernize legacy implementations (C / Makefiles),
- Create WestBox framework with main features:
  - Data Acquisition,
  - Timing Network,
  - Finite States Machines,
  - Shared Memory Network,
- Make cross-platform based on CMake.

Still in operation :

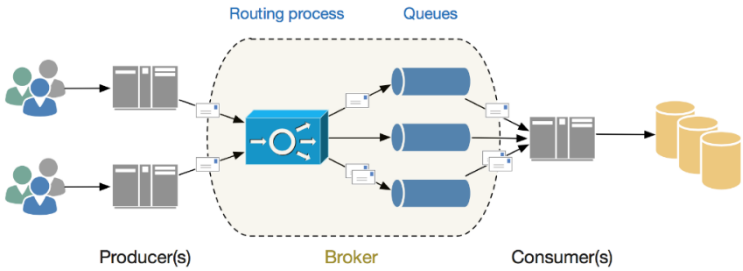
- A proprietary legacy MOM (Message Oriented Middleware),
- Based on RTWorks - SmartSockets, TIBCO
- Based on publish-subcribe architecture,
- To synchronize units,
- To exchange data.

➔ **Used with all CODAC actors from local network.**

RTWorks:

- Used since the 1990,
- Use a broker (Deneb) to queue and dispatch messages over topics,
- Different levels of Quality of Service (QoS),
- Serialize data automatically (opaque),
- Available under Linux, Windows, and LynxOS.

- **No** acknowledgment,
- **No** persistent sessions,
- **No** efficient support for multi-threading,
- **No** gateway,
- **No** chaining,
- **Not** a standard (proprietary).



- **No** topics map,
- **No** helper tools (log, monitoring),
- **No more technical support,**
- **Out-of-date** documentation and outdated frozen version,
- Limited capacity reached at IRFM (overload).

➔ **Need to find a replacement.**

History :

- **2002**: list of dysfunctions from RTWorks,
- Broker overload identification,
- No solution without expensive software upgrade.

- **2010**: prototype to port to Notify (proprietary SDK),
- Require a gateway to work with RTWorks,
- Expensive supports,
- Complex integration in IRFM framework,
- No efficient results,
- Notify not selected as suitable alternative.

- **2017**: review of industrial MOM solutions,
- AMQP, ActiveMQ, RabbitMQ (Cern / ITER),
- Mqtt (used at **RJH - Cadarache**),
- Visit of RJH test-bench (CAREDAS project),
- Good feedback CAREDAS team.

➔ **Mqtt must be evaluated at IRFM.**

Jules Horowitz Research Reactor

Prototyping with Mqtt :

- **2018** : installation of Mqtt V3.1 test-bench at IRFM,
- First prototype in IRFM framework,
- First tests with Mosquitto C framework.

- **2019** : first use to handle the state machine of data acquisition units,
- Port whole framework API for fast controllers,
- Implement bi-lingual clients (RTWorks / Mqtt),
- First try with Mqtt as secondary MOM,
- To relieve RTWorks infrastructure,
- First uses of Mqtt during the C4 West experimental campaign.

- **2020** : review of open source Mqtt brokers (VerneMq, Mosquitto, etc.),
- Limit tests and final broker selection,
- Finalization of clients migration and topic map,
- First use of Mqtt with fast controllers during C5.

➔ **Mqtt selected as suitable MOM with Mosquitto broker for WEST.**

Mqtt:

- Like RTWorks but better,

- Uses a broker to Queue and dispatch messages Over topics,
- Different levels of Quality of Service (QoS),
- Available under Linux, Windows, and LynxOS,
- Acknowledgment and persistent sessions,
- Gateway and chaining (WebSockets),
- Supports multi-threading and secure connexions.

- **OASIS Standard**, very well documented,
- Large community, IoT, industry,
- Open-source solutions,
- Interchangeable and multi-protocol brokers,
- Interoperable clients.

- **No automatic data serialization.**

➔ **Need to define a model to communicate and a topic map.**

Communication:

- To exchange data between actors,
- Mqtt transport information as byte-array,
- We needs to define a data model,
- To encapsulate information.

➔ **Zlib compressed XML**

- Zlib is fast and portable everywhere,
- XML is a mature standard,
- Both available as shared libraries.

Model:

- Structured by 2 fields,
- Metadata,
  Topic, sender, version UUID, date, …
- Body with properties list,
  Bool, byte-array, double, string, int, …

```
<?xml version='1.0'?>
<Message>
  <Metadata>
    <Topic Value="/IRFM/MOM/RECIPIENT/DVME1/"/>
    <Sender Value="GC169574@intra.cea.fr:momxmldata_test:1234"/>
    <Version Value="1.0.0"/>
    <Uuid Value="564abb17-0832-4ce5-bc79-511670ff0d03"/>
    <TimeStamp Value="2019-01-15T15:04:56"/>
  </Metadata>

  <Body>
    <ShotID Value="32768"/>
    <DataItemList Value="4">
      <DataItem Value="1">
        <Name Value="DVME1_value1_integer"/>
        <Type Value="INT"/>
        <Data Value="1414"/>
      </DataItem>
      <DataItem Value="2">
        <Name Value="DVME1_value2_float"/>
        <Type Value="DOUBLE"/>
        <Data Value="1.7319999933242798"/>
      </DataItem>
          …
        </DataItemList>
  </Body>
</Message>
```

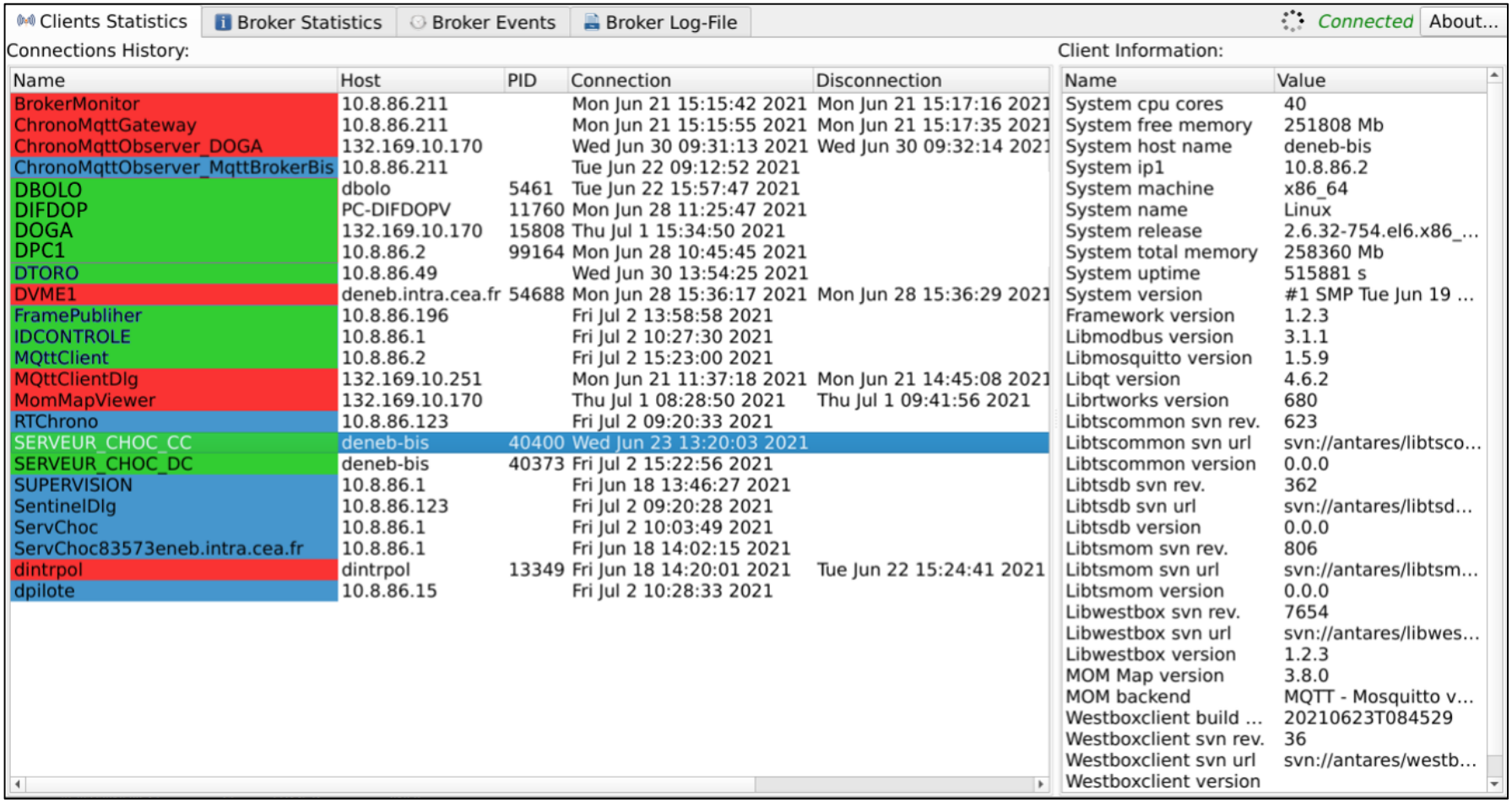
Topic map:

- Topics as paths,
- For each communication channels,
- Shared between all actors,
- Infrastructure topics :
  Sync, Events, Log, Tests,
- CODAC service topics :
  Supervision, Servers, IHM, Plasma Control System, etc.,
- Fast controller topics,
  Spectrometry, security, reflectometry, thermography, Heating, Gas, etc.

Custom tools for debugging and monitoring :

- A Qt frontend to monitor messages,
  Payload contents, real time data, curves, events,

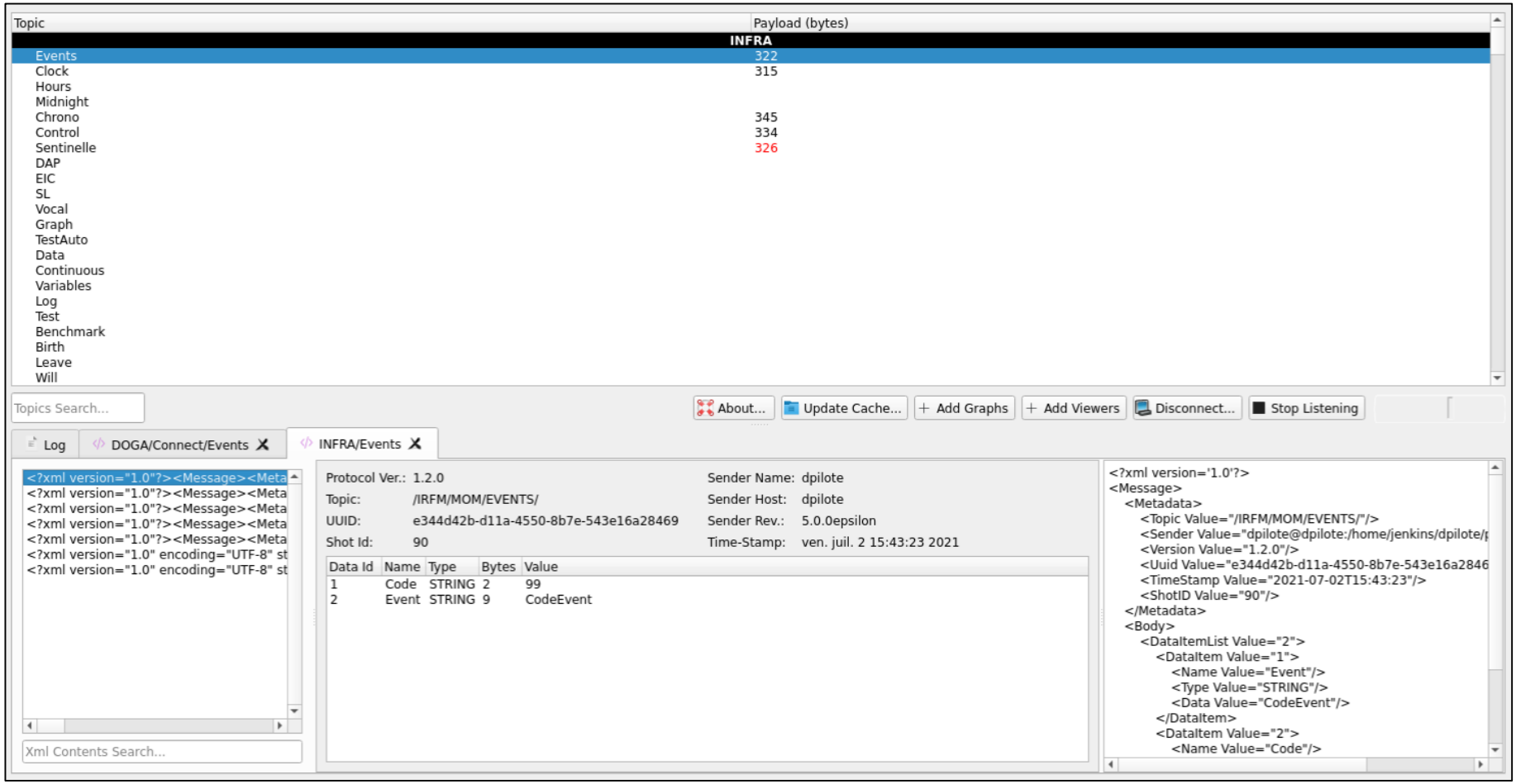
- A Qt / WebAssembly frontend to monitor the broker,
  Connections, statistics, events, logs.



Name	Host	PID	Connection	Disconnection
BrokerMonitor	10.8.86.211		Mon Jun 21 15:15:42 2021	Mon Jun 21 15:17:16 2021
ChronoMqttGateway	10.8.86.211		Mon Jun 21 15:15:55 2021	Mon Jun 21 15:17:35 2021
ChronoMqttObserver_DOGA	132.169.10.170		Wed Jun 30 09:31:13 2021	Wed Jun 30 09:32:14 2021
ChronoMqttObserver_MqttBrokerBis	10.8.86.211		Tue Jun 22 09:12:52 2021	
DBOLO	dbolo	5461	Tue Jun 22 15:57:47 2021	
DIFDOP	PC-DIFDOPV	11760	Mon Jun 28 11:25:47 2021	
DOGA	132.169.10.170	15808	Thu Jul 1 15:34:50 2021	
DPC1	10.8.86.2	99164	Mon Jun 28 10:45:45 2021	
DTORO	10.8.86.49		Wed Jun 30 13:54:25 2021	
DVME1	deneb.intra.cea.fr	54688	Mon Jun 28 15:36:17 2021	Mon Jun 28 15:36:29 2021
FramePubliher	10.8.86.196		Fri Jul 2 13:58:58 2021	
IDCONTROLE	10.8.86.1		Fri Jul 2 10:27:30 2021	
MQttClient	10.8.86.2		Fri Jul 2 15:23:00 2021	
MQttClientDlg	132.169.10.251		Mon Jun 21 11:37:18 2021	Mon Jun 21 14:45:08 2021
MomMapViewer	132.169.10.170		Thu Jul 1 08:28:50 2021	Thu Jul 1 09:41:56 2021
RTChrono	10.8.86.123		Fri Jul 2 09:20:33 2021	
SERVEUR_CHOC_CC	deneb-bis	40400	Wed Jun 23 13:20:03 2021	
SERVEUR_CHOC_DC	deneb-bis	40373	Fri Jul 2 15:22:56 2021	
SUPERVISION	10.8.86.1		Fri Jun 18 13:46:27 2021	
SentinelDlg	10.8.86.123		Fri Jul 2 09:20:28 2021	
ServChoc	10.8.86.1		Fri Jul 2 10:03:49 2021	
ServChoc83573eneb.intra.cea.fr	10.8.86.1		Fri Jun 18 14:02:15 2021	
dintrpol	dintrpol	13349	Fri Jun 18 14:20:01 2021	Tue Jun 22 15:24:41 2021
dpilote	10.8.86.15		Fri Jul 2 10:28:33 2021	

Name	Value
System cpu cores	40
System free memory	251808 Mb
System host name	deneb-bis
System ip1	10.8.86.2
System machine	x86_64
System name	Linux
System release	2.6.32-754.el6.x86_...
System total memory	258360 Mb
System uptime	515881 s
System version	#1 SMP Tue Jun 19 ...
Framework version	1.2.3
Libmodbus version	3.1.1
Libmosquitto version	1.5.9
Libqt version	4.6.2
Librtworks version	680
Libtscommon svn rev.	623
Libtscommon svn url	svn://antares/libtsco...
Libtscommon version	0.0.0
Libtsdb svn rev.	362
Libtsdb svn url	svn://antares/libtsd...
Libtsdb version	0.0.0
Libtsmom svn rev.	806
Libtsmom svn url	svn://antares/libtsm...
Libtsmom version	0.0.0
Libwestbox svn rev.	7654
Libwestbox svn url	svn://antares/libwes...
Libwestbox version	1.2.3
MOM Map version	3.8.0
MOM backend	MQTT - Mosquitto v...
Westboxclient build ...	20210623T084529
Westboxclient svn rev.	36
Westboxclient svn url	svn://antares/westb...
Westboxclient version	

Mosquitto broker Qt/WebAssembly Monitoring



IRFM Mqtt Message viewer by Topic

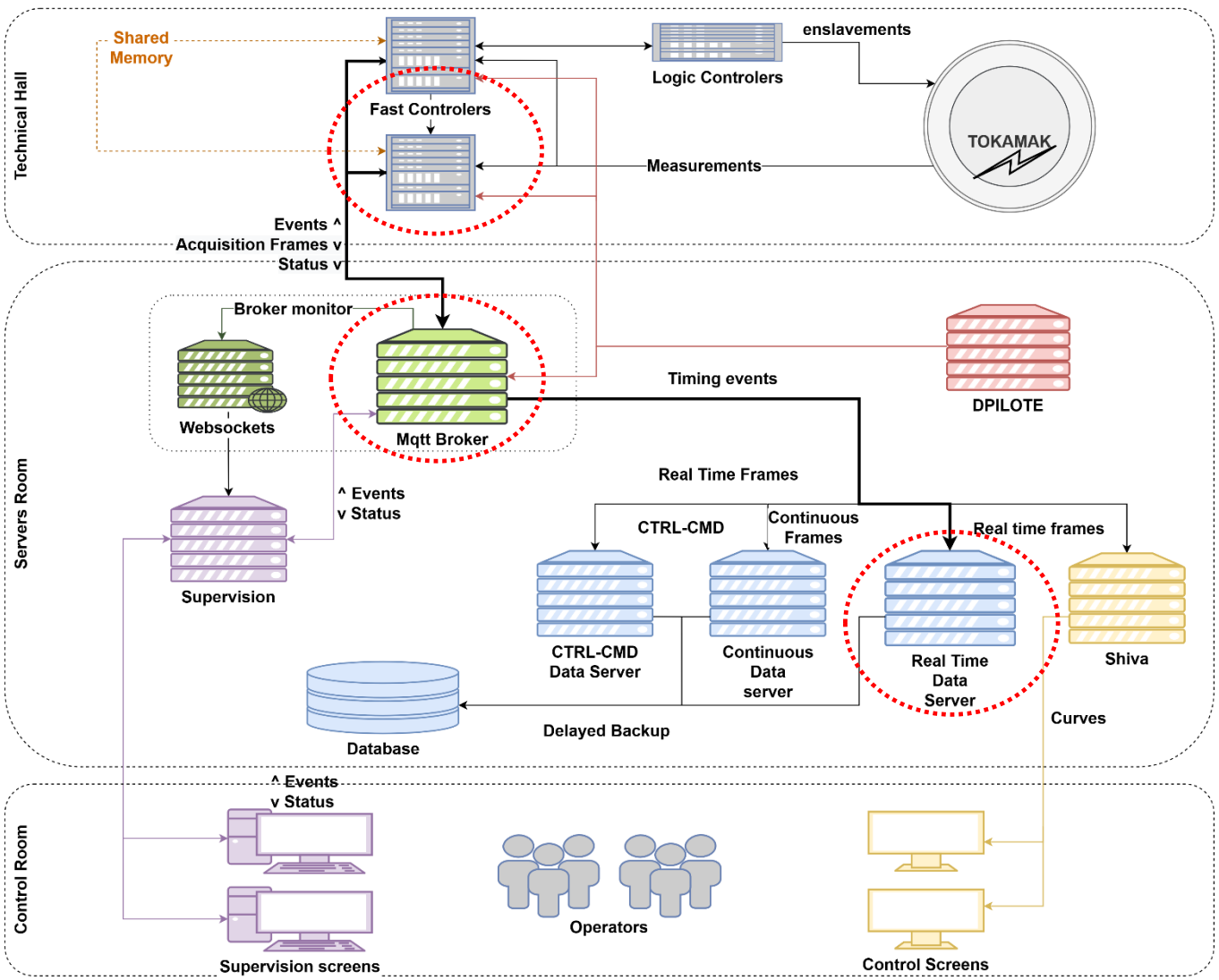
WEST CODAC Architecture

➔ Map defined with more than 1500 topics

➔ For 80 Actors on the network

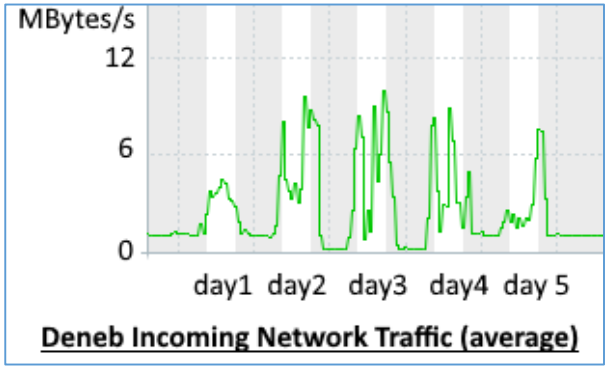
➔ A bottleneck :

20 x Fast controllers
→
Mqtt broker
→
Real-time Data Server



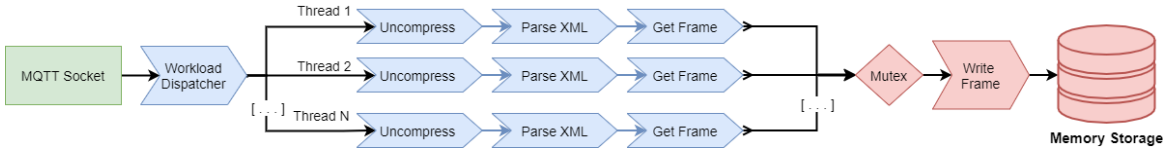
Mqtt Chain Test-bench Environment :

- During experiments → RTWorks chain overload,
- **Bottleneck : real-time data from fast controllers,**
- Sent to the database server (one core processing),
- **5 MBytes/s during 1mn,**
- Post-processing in Matlab show random data loss.



- IRFM Mqtt chain test-bench → check the limits with same conditions,
- Fast Controllers, Broker, Real-time Data Server,
- Fast Controllers emit real-time data frames (sampled at 1ms),
- **Output traffic : 0.1 MBytes/s by fast controller**,
- 20 emulated fast controllers.

Mqtt Real-time Data Server :



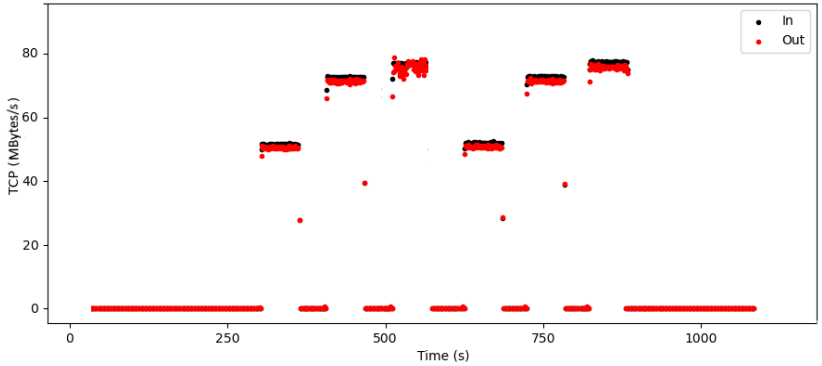
- Ported to Qt based WestBox framework,
- 1 receptor : max input traffic **16 MBytes/s**,
  80% CPU, no frame lost,
- Multi-threaded frame receptor : 8 cores → **≈ 100 MBytes/s**.

Mqtt Chain Test-bench Results:

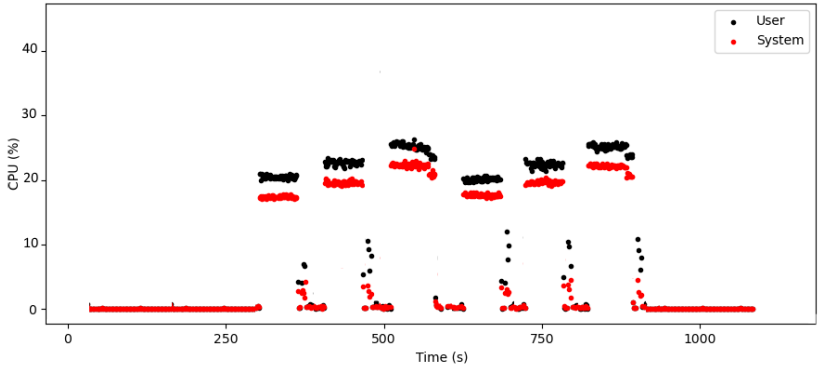
- Mqtt chain supports 5 MBytes/s as RTWorks,
- Can go much higher :
  Up to 70 MBytes/s without loosing real-time frames !
  Less than 60% of CPU usage with 8 threads RT data server.
  Can be extended with more cores on RT data server.

Mosquitto Framework as Mqtt Solution:

- Works as expected in production,
- Good performance with multi-threaded support,
- **Hence Mqtt is a Long-term powerful solution for the future at IRFM.**



Mqtt Broker TCP Traffic



8 cores RT Data Server CPU usage

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