Next-Generation MADOCA for The SPring-8 Control Framework

T. Matsumoto, Y. Furukawa, M. Ishii
JASRI/SPring-8
Outline

• Introduction to MADOCA
• MADOCA II Messaging
• MADOCA II Applications
• Summary
Introduction to MADOCA

• Control Framework originally developed at SPring-8, Japan

• Adopted in several facilities for various control applications
  – SPring-8, SACLA, NewSUBARU, HiSOR
  – Accelerator, beamline and experimental station controls

• Successfully utilized since 1997

*Photos courtesy of RIKEN/JASRI
Control Framework originally developed at SPring-8, Japan
- **Message And Database Oriented Control Architecture**
- Adopted in several facilities for various control applications
  - SPring-8, SACLA, NewSUBARU, HiSOR
  - Accelerator, beamline and experimental station controls
- Successfully utilized since 1997

*Photos courtesy of RIKEN/JASRI*
MADOCA Messaging

• Based on a text command with S/V/O/C syntax
  – **Subject, Verb, Object, Complement**
  – Examples:
    – `<S>/put/sr_mag_ps_b/on`
    – `<S>/get/sr_vac_ivg_19_ab3/pressure`
  – Unique for object name to identify control equipment
  – `<S> = 123_matumot_oprgui_opcon01` (example)
    → from PID, user name, application name and host name
  – Replies are returned from the equipment
MADOCA Messaging

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    – sr_mag_ps_b/put/<S>/ok
    – sr_vac_ivg_19_abs/get/<S>/1.23E-09Pa
MADOCA Messaging

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• Human-readable messages (abstracted)
  – Do not include specific controls on each device
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• Human-readable messages (abstracted)
  – Do not include specific controls on each device

→ These features are essential in our control system
MADOCA Control Framework

- Operator WS
- GUI
- Message Server
- Access Server
- Equipment Manager
- Devices

System V IPC
ONC/RPC

Front-end computers (VME, µTCA, …)
MADOCA Control Framework

Shortcomings

- Operator WS
- GUI
- Message Server
- Access Server
- Equipment Manager
- Devices

Front-end computers (VME, µTCA, ...)

System V IPC

ONC/RPC

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MADOCA Control Framework

Shortcomings

- SVOC length ≤ 255 characters
- Not suitable to transmit variable length-data
- Waveform, Image data

Front-end computers (VME, µTCA, ...)

Operator WS

Message Server

Access Server

GUI

Access Server

Equipment Manager

Devices

Devices

System V IPC

ONC/RPC

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MADOCA Control Framework

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  - Used only for Linux, Solaris
    - Due to System V IPC, ONC/RPC

Front-end computers (VME, µTCA, ...)

System V IPC

ONC/RPC
MADOCA Control Framework

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    - Waveform, Image data
- Lack of controls on Windows
  - Used only for Linux, Solaris
    - Due to System V IPC, ONC/RPC
- Synchronous communication in ONC/RPC
  - Need to wait to finish processing of each message

Diagram:

- Operator WS
- GUI
- Message Server
- Access Server
- Equipment Manager
- Devices
- Front-end computers (VME, µTCA, ...)

System V IPC

ONC/RPC

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Next-Generation MADOCA, MADOCA II

• Keep messaging format of MADOCA
• Fix shortcomings in MADOCA
Next-Generation MADOCA, MADOCA II

• Keep messaging format of MADOCA
• Fix shortcomings in MADOCA

✔ Messaging with ZeroMQ/MessagePack
✔ Data logging with NoSQL (Cassandara, Redis)
  → Refer M.Kago et al. on TUPPC08
    – “Development of a Scalable and Flexible Data Logging System Using NoSQL Databases”
MADOCA

- Operator WS
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System V IPC

ONC/RPC

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MADOCA

Operator WS

GUI

Message Server

Access Server

Equipment Manager

Devices

Front-end computers (VME, µTCA, ...)

System V IPC

ONC/RPC

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MADOCA

Operator WS

GUI

GUI

Message Server

Access Server

Access Server

Equipment Manager

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Front-end computers (VME, µTCA, ...)

System V IPC

ONC/RPC

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MADOCA

Operator WS

Message Server

Access Server

Access Server

Equipment Manager

Devices

Devices

Front-end computers (VME, µTCA, …)

System V IPC

ONC/RPC

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MADOCA

Operator WS

GUI

Message Server

Access Server

Equipment Manager

Devices

System V IPC

ONC/RPC

Front-end computers (VME, µTCA, …)

MADOCA II

Operator WS

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MADOCA

Operator WS

GUI

Message Server

Access Server

Access Server

Equipment Manager

Devices

Front-end computers (VME, µTCA, …)

System V IPC

ONC/RPC

MADOCA II

Operator WS

Message Server 2

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MADOCA

Operator WS → GUI → Message Server → Access Server → Equipment Manager → Devices

Front-end computers (VME, μTCA, …)

System V IPC

ONC/RPC

MADOCA II

Operator WS → GUI → Message Server 2

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MADOCA

Operator WS ➔ GUI ➔ Message Server ➔ Access Server ➔ Equipment Manager ➔ Devices

System V IPC

ONC/RPC

Front-end computers (VME, μTCA, …)

MADOCA II

Operator WS ➔ GUI ➔ Message Server 2

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MADOCA

- Operator WS
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Front-end computers (VME, \( \mu \)TCA, …)

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MADOCA

Operator WS

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ONC/RPC

Front-end computers (VME, \( \mu \)TCA, …)

MADOCA II

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Message Server 2

GUI

Front-end computers (VME, \( \mu \)TCA …)
MADOCA

Front-end computers (VME, µTCA, …)

Equipment Manager

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Operator WS

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MADOCA II

Devices

Devices

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MADOCA

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Message Server

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MADOCA

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GUI

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GUI

Message Server 2

GUI

Access Server

Devices

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MADOCA

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Access Server

Equipment Manager

Devices

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System V IPC

MADOCA II

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Access Server

Equipment Manager 2

Devices

Equipment

Manager

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Message

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Access

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MADOCA II

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MADOCA

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Access Server
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Devices

Front-end computers (VME, µTCA …)
MADOCA

Front-end computers (VME, μTCA, …)

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<tr>
<th>System V IPC</th>
<th>ONC/RPC</th>
</tr>
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<tr>
<td>Operator WS</td>
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</tr>
<tr>
<td>GUI</td>
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</tr>
<tr>
<td>Access Server</td>
<td>Access Server</td>
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<td>Equipment Manager</td>
<td>Devices</td>
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</tbody>
</table>

MADOCA II

Front-end computers (VME, μTCA …)

<table>
<thead>
<tr>
<th>ZeroMQ</th>
<th>Operator WS</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUI</td>
<td>Message Server 2</td>
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<tr>
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MADOCA

Front-end computers (VME, µTCA, …)

Equipment Manager

Access Server

Message Server

GUI

Operator WS

ONC/RPC

System V IPC

MADOCA II

Front-end computers (VME, µTCA, …)

Equipment Manager 2

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Operator WS

ZeroMQ
MADOCA

- Operator WS
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System V IPC

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ZeroMQ
MADOCA

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Operator WS

System V IPC

ONC/RPC

MADOCA II

Front-end computers (VME, µTCA, …)

Equipment Manager 2

Access Server

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GUI

Operator WS

ZeroMQ
ZeroMQ @ MADOCA II (1)

✓ Messaging with Variable-length data

S/V/O/C

✓ Multi-OS
  - Can be used for Linux, Solaris

✓ Multi-languages
  - MADOCA II has been written in C++
ZeroMQ @ MADOCA II (1)

✔ Messaging with Variable-length data
  
  S/V/O/C +

✔ Multi-OS
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✔ Messaging with Variable-length data

S/V/O/C + Waveform, Image data etc. (if required)

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S/V/O/C + Waveform, Image data etc. (if required)

✓ Multi-OS
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✓ Multi-languages
  – MADOCA II has been written in C++
    Also applied to Python and LabVIEW so far
ZeroMQ @ MADOCA II (2)

✓ Asynchronous communications

• No need to wait to finish processing of each message
ZeroMQ @ MADOCA II (2)

Asynchronous communications

- No need to wait to finish processing of each message
  - Message ID is assigned to each message to handle the relation between sending and reception
ZeroMQ @ MADOCA II (2)

Asynchronous communications

- No need to wait to finish processing of each message
  - Message ID is assigned to each message to handle the relation between sending and reception
- Distributed processing of control messages
  - Multiple Equipment Managers can help
MessagePack @MADOCA II (1)

Used for Serialization of Messaging data

✔ Message exchange among different computing environments
  – byte-order procedures are managed
MessagePack @MADOCA II (1)

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Used for Serialization of Messaging data

✔ Message exchange among different computing environments
   - byte-order procedures are managed

✔ Flexible data formats
   → Applied to variable-length data, No size limit
MessagePack @MADOCA II (1)

Used for Serialization of Messaging data

✓ Message exchange among different computing environments
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Array
MessagePack @MADOCA II (1)

Used for Serialization of Messaging data

☑ Message exchange among different computing environments
  - byte-order procedures are managed

☑ Flexible data formats
  → Applied to variable-length data, No size limit

Array [ 1.23, 4.56, 7.89, ... ]
MessagePack @MADOCA II (1)

Used for Serialization of Messaging data

✔️ Message exchange among different computing environments
  - byte-order procedures are managed

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Map
**MessagePack @MADOCA II (1)**

Used for Serialization of Messaging data

✓ Message exchange among different computing environments
  – byte-order procedures are managed

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  → Applied to variable-length data, No size limit

Array \[ [1.23, 4.56, 7.89, \ldots] \]

Map \{ “image_data_type” : “MONO”, “image_data” : [1,3,5,\ldots] \}
MessagePack @MADOCA II (1)

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✔ Message exchange among different computing environments
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Array [ 1.23, 4.56, 7.89, … ]  → Waveform

Map { “image_data_type” : “MONO”,
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Used for Serialization of Messaging data

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Map { “image_data_type” : “MONO”, “image_data” : [1, 3, 5, …] }
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<table>
<thead>
<tr>
<th>Key</th>
<th>Data format</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>image_data_type</td>
<td>string</td>
<td>“MONO”, “RGB”, “RGBA”</td>
</tr>
<tr>
<td>image_width</td>
<td>int32_t</td>
<td></td>
</tr>
<tr>
<td>image_height</td>
<td>int32_t</td>
<td></td>
</tr>
<tr>
<td>image_depth</td>
<td>int32_t</td>
<td></td>
</tr>
<tr>
<td>image_num_type</td>
<td>string</td>
<td>“int32_t”, “uint16_t”, “uint32_t”, “uint64_t”, “int16_t”, “int32_t”, “int64_t”, “float”, “double”</td>
</tr>
<tr>
<td>image_data</td>
<td>defined by [image_num_type]</td>
<td>→Array</td>
</tr>
<tr>
<td>image_pixel_order</td>
<td>string</td>
<td>“lefttop”, “leftbottom”</td>
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## MessagePack @MADOCA II (2)

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Key’s can be flexibly added by users
MADOCA II Performance (1)

Operator WS
Core i7-2670QM 2.2GHz

Network
GbE cable
* Direct connection

Front-end computer
Core 2Duo P9500 2.53GHz

Message Send
Message size 80 byte

• Round Trip Time (RTT)
  – 1.2 msec / message
  > 850 Hz

Message size 80 byte

• Round Trip Time (RTT)
  – 1.2 msec / message
  > 850 Hz

Send
Reply
MADOCA II Performance (2)

- "Real-time Process control on Multi-core Processors"
  - MOPPC128  M. Ishii et al.

- RTT < 2ms
  - With binding processes into real-time class
  → Real-time control
MADOCA II @ BL36XU beamline
Since Sep. 2012

MADOCA II

GUI
GUI

Message Server 2

Equipment Manager 2
Equipment Manager 2

Devices
Devices

BL36XU Operator WS
ZeroMQ

Beamline Front-end computer

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MADOCA II @ BL36XU beamline

Since Sep. 2012

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GUI

GUI

Message Server 2

ZeroMQ

BL36XU Operator WS

Equipment Manager 2

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Since Sep. 2012
MADOCA II @ BL36XU beamline
Since Sep. 2012

MADOCA II

- GUI
- GUI
- Message Server 2
- ZeroMQ
- BL36XU Operator WS
- Equipment Manager 2
- Equipment Manager 2
- Devices
- Devices

VME for Insertion Device

Beamline Front-end computer

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MADOCA II @ BL36XU beamline
Since Sep. 2012

VME for Insertion Device

BL36XU Operator WS

ZeroMQ

Beamline Front-end computer

GUI

Message Server 2

Equipment Manager 2

Devices

Equipment Manager 2

Devices

Message Server 2

GUI

GUI

Devices
MADOCA II @ BL36XU beamline

Since Sep. 2012

MADOCA II

BL36XU Operator WS

ZeroMQ

VME for Insertion Device

Devices

Equipment Manager 2

Equipment Manager 2

Message Server 2

Message Server 2

GUI

GUI

Beamline Front-end computer

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MADOCA II @ BL36XU beamline
Since Sep. 2012

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GUI
GUI
Message Server 2

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Equipment Manager
Equipment Manager

Devices
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VME for Insertion Device

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Devices

GUI

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Control Room Operator WS

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Equipment Manager

Devices

Message Server 2

GUI

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Beamline Front-end computer

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Message Server 2

GUI

GUI

Message Server 2

Equipment Manager 2

Equipment Manager 2

Devices

Devices

ZeroMQ

8 Oct 2013, ICALEPCS 2013, San Francisco, California
MADOCA II @ BL36XU beamline
Since Sep. 2012

Control Room Operator WS

BL36XU Operator WS

ZeroMQ

VME for Insertion Device

Beamline Front-end computer

8 Oct 2013, ICALEPCS 2013, San Francisco, California
MADOCA II @ BL36XU beamline

Since Sep. 2012

Control Room Operator WS

Message Server

Access Server

VME for Insertion Device

Equipment Manager

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GUI

GUI

Message Server

BL36XU Operator WS

ZeroMQ

Beamline Front-end computer

Message Server 2

Equipment Manager

Devices

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MADOCA II
MADOCA II @ BL36XU beamline

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Control Room Operator WS

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Access Server

Equipment Manager
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VME for Insertion Device

BL36XU Operator WS
GUI
Message Server 2
Access Server

Equipment Manager
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Devices

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Beamline Front-end computer

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Message Server
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Access Server
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VME for Insertion Device

Equipment Manager

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GUI

Message Server 2

GUI

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Message Server 2

GUI

GUI

Access Server

Access Server

Equipment Manager 2

Equipment Manager 2

Devices

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8 Oct 2013, ICALEPCS 2013, San Francisco, California
MADOCA II @ BL36XU beamline
Since Sep. 2012

MADOCA

- Control Room Operator WS
- Message Server
- Access Server
- Equipment Manager
- VME for Insertion Device

MADOCA II

- BL36XU Operator WS
- Message Server 2
- Equipment Manager 2
- Beamline Front-end computer
- ZeroMQ

VME for Insertion Device
MADOCA II @ BL36XU beamline

Since Sep. 2012

Control Room Operator WS
System V IPC
VME for Insertion Device

MADOCA

GUI
GUI

Message Server
Message Server

Access Server
Access Server

Equipment Manager

Devices

MADOCA II

GUI
GUI

Message Server 2

Access Server

Equipment Manager

Equipment Manager 2

Devices

Devices

BL36XU Operator WS
ZeroMQ
Beamline Front-end computer

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Since Sep. 2012

MADOCA

GUI

Message Server

Access Server

Access Server

Equipment Manager

Devices

MADOCA II

GUI

Message Server 2

Access Server

Access Server

Equipment Manager 2

Equipment Manager 2

Devices

Devices

Control Room Operator WS

System V IPC

ONC/RPC

VME for Insertion Device

BL36XU Operator WS

ZeroMQ

Beamline Front-end computer

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MADOCA II @ BL36XU beamline
Since Sep. 2012

Control Room Operator WS
System V IPC
ONC/RPC
VME for Insertion Device

MADOCA
- GUI
- Message Server
- Access Server
- Equipment Manager
- Devices

MADOCA II
- GUI
- Message Server 2
- Equipment Manager 2
- Devices

ONC/RPC
System V IPC
ZeroMQ

Beamline Front-end computer

8 Oct 2013, ICALEPCS 2013, San Francisco, California
MADOCA II @ BL36XU beamline
Since Sep. 2012

MADOCA

- GUI
- Message Server
- Access Server
- Equipment Manager
- Devices

MADOCA II

- GUI
- Message Server 2
- Equipment Manager
- Devices

Control Room Operator WS
System V IPC
ONC/RPC
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BL36XU Operator WS
ZeroMQ
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Since Sep. 2012

Control Room Operator WS
System V IPC
ONC/RPC
VME for Insertion Device

MADOCA

GUI
Message Server
Access Server
Access Server
Equipment Manager
Devices

MADOCA II

GUI
Message Server 2
Access Server 2
Access Server 2
RPC_MS2
Equipment Manager 2
Devices

BL36XU Operator WS
ZeroMQ
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Since Sep. 2012

MADOCA

- GUI
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- Access Server
- Equipment Manager
- Devices

MADOCA II

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- Equipment Manager 2
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System V IPC
ONC/RPC
VME for Insertion Device
ZeroMQ
Beamline Front-end computer
BL36XU Operator WS
Control Room Operator WS

8 Oct 2013, ICALEPCS 2013, San Francisco, California
MADOCA II Applications

• “MADOCA II Interface with LabVIEW”
  – MOPPC129  Y. Furukawa et al.
  – Applied to Beam Position Monitor (BPM)
  – Waveform, 20k points/sec
  – Running on Windows
  – LabVIEW protocol for MADOCA II
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• “Development of MicroTCA-based Image Processing System at SPring-8”
  – TUPPC088  A. Kiyomichi et al.
  – Applied to two-dimensional synchrotron interferometer
  – Image data (VGA), up to 10 Hz
Summary

• New control framework, MADOCA II has been developed
  – Shortcomings in MADOCA are fixed
  – Flexibilities in the Messaging using ZeroMQ/MessagePack
    – Messaging with variable-length data
    – Asynchronous communications
    – Controls on Linux, Solaris and Windows

• Control systems with MADOCA II are implemented
  – Stabilities → confirmed in BL36XU beamline since Sep. 2012
  – BPM and two-dimensional interferometers
  – SACLA experimental station controls

• Next step: utilize MADOCA II for various applications
  – Upgrade & Replacement of SPring-8 control systems
  – Apply MADOCA II into other facilities