Piotr P. Nikiel

The SoC workshop at CERN

OPC-UA, quasar and SoCs

14-Jun-2019

Part 1

Making a simple OPC-UA server
on a laptop
to play with

Making a simple OPC-UA server (1)

- Plan:
  - Make an empty quasar-based server,
  - Build, run; connect with an OPC-UA client
  - Design some simple monitoring and control: switch, LED, analog sensor monitoring (with fake data)

Making a simple OPC-UA server (2)

Make an empty quasar-based server

- Create the empty server:
  - cd $QUASAR
  - ./quasar.py create_project ~/gitProjects/SoC_Workshop_Quasar
  - cd ~/gitProjects/SoC_Workshop_Quasar
  - ./quasar.py set_build_config $QUASAR/open62541_config.cmake
  - ./quasar.py enable_module open62541-compat v1.1.2
  - git init .
  - git add *
  - git commit -a -m "Initial version"
- Build and run it:
  - ./quasar.py build
  - cd build/bin
  - ./OpcUaServer
- Connect using UaExpert

Making a simple OPC-UA server (3)

Look around

- We recommend Eclipse CDT
  - … because we will need its XML tools etc.
- Integrate a quasar project into Eclipse:
  - create an empty C++ project from the project path
- Relevant files for a developer:
  - Design/Design.xml
    Entry-point to modeling!
  - Server/src/QuasarServer.cpp
    Server init/ shutdown and “main loop”
  - Device/src for Device logic classes
    will add them later

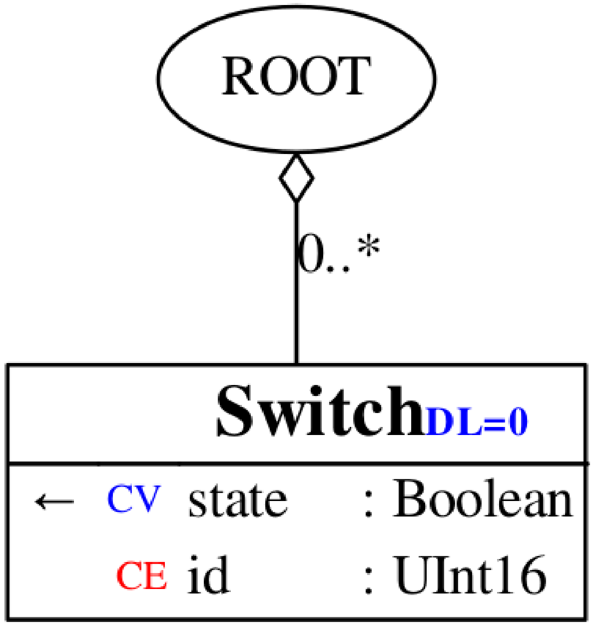
Making a simple OPC-UA server (4)
Enter design!

- Open Design in Eclipse
  - Eclipse is pretty good for schema-based XML editing
- Design can be easily visualized
  - ./quasar.py generate diagram 3
    (number is the detail level)
- General principle:
  - classes represent types of control system objects
  - variables are to exchange information
    (writing, reading, monitoring)
  - variables belong to classes
  - classes can be nested in tree-like hierarchies

Making a simple OPC-UA server (5)

Let's add a simple class...

- Adding a Switch quasar class
  - for hardware guys: we will use it to monitor real switches – via digital inputs – on the board
- Add a quasar cache-variable state
  - it will follow the switch state in runtime
- Since one class will cover many objects, I will add a switch identifier on the board
  - using quasar config-entry
- Refresh the design visualization
- Rebuild …
- Add objects in the config file …
- Rerun ...



Making a simple OPC-UA server (6)

... let’s exchange information ...

- In quasar servers, the integration with developer’s code **usually** goes to Device Logic
  - there are other ways too ...
- Our design:
  - add Device Logic to Switch class
- Generate device class
  - ./quasar.py generate device Switch
  - and build the server… (because we changed the Design)
- Let’s have a good look at the Device class ...
- Let’s add a method **update** that will poll the switch state and publish it via OPC-UA
  - … for the moment with fake (i.e. random) data:

```
bool state = rand() & 1;
getAddressSpaceLink()->setState(state, OpcUa_Good);
```

Making a simple OPC-UA server (7)

... let's exchange information ...

- The update method might be called from the server's main loop for simplicity:

```
for (Device::DSwitch* sw : Device::DRoot::getInstance()→switchs())
    sw→update();
```

- Build, run the server and see in UaExpert
- To polish up:

```
./quasar.py check_consistency --ask
```

- Commit & tag, e.g. as v1

```
git commit -a -m 'Fake readout of the switch'
git tag -a v1
```

Making a simple OPC-UA server (8)

… note ...

- The build & deployment strategy you just saw is appropriate for:
  - desktops and servers (Windows and Linux)
  - cross-compilers distributed as SDKs (with rootfs/sysroot)
    - quasar can be told to use a chosen cross-compiler
  - embedded systems with native compilation
- For Yocto/PetaLinux:
  - software design & development procedure is identical
  - building is different – quasar server integrates as Yocto recipe/PetaLinux app

Questions?
(… so far …)

… and 1-minute break ...

Part 2

Towards the demo

PetaLinux + quasar
On
Zybo Z7-20 development board

PetaLinux + quasar (1)
Plan

- Build our earlier project in PetaLinux (still with fake data)
- Deploy on real hardware, connect, etc…
- Integrate real I/O

PetaLinux + quasar (2): Reference versions and settings

- PetaLinux 2017.4
- Zybo Z7-20 BSP: v2017.4-3
- quasar: v1.3.4
- open62541-compat: v1.1.2 (!)
- Host OS:
  CentOS Linux release 7.6.1810 (Core)
- source /opt/pkg/petalinux/settings.sh
- export QUASAR=~/gitProjects/quasar
- alias zybo_package='petalinux-package --boot --fpga images/linux/system_wrapper.bit --u-boot --force'

PetaLinux + quasar (3): PetaLinux step-by-step

- In our quasar project dir:
  - Deploy CMake Epilogue (will tell PetaLinux what are server deliverables):
    ```
    cp -v $QUASAR/Extra/yocto/CMakeEpilogue.cmake .
    git add CMakeEpilogue.cmake
    ```
  - Deploy build configuration for Yocto/PetaLinux:
    ```
    cp -v $QUASAR/Extra/yocto/yocto_open62541_config.cmake .
    git add yocto_open62541_config.cmake
    ./quasar.py set_build_config yocto_open62541_config.cmake
    ```
  - Force quasar CMake headers as source:
    ```
    ./quasar.py generate cmake_headers
    cp build/AddressSpace/cmake_generated.cmake AddressSpace
    cp build/Device/generated/cmake_header.cmake Device/generated
    git add AddressSpace/cmake_generated.cmake -f
    git add Device/generated/cmake_header.cmake -f
    ```
  - Tag it all together
    ```
    git commit -a
    git tag -a v2
    ```
  - The project should still build on the host after this ;-)

PetaLinux + quasar (3): PetaLinux step-by-step

- *Note: using vanilla built image of PetaLinux. (Otherwise we'd need 30-60 minutes to get it built from scratch…)*
- Step 1 – create the app in PetaLinux:
  `petalinux-create -t apps --template install -n opcua-server --enable`
- Step 2 – replace the recipe (BB file) with one shipped by quasar
  `cp $QUASAR/Extra/yocto/my-opcua-server.bb project-spec/meta-user/recipes-apps/opcua-server/opcua-server.bb`
- Step 3 – you might need extra recipes, depending on PetaLinux versions (all shipped with quasar). I need:
  - python-enum34, xsd,
    `cp $QUASAR/Extra/yocto/xsd_4.0.0.bb project-spec/meta-user/recipes-apps/opcua-server/`
    `cp $QUASAR/Extra/yocto/python-enum34_1.1.6.bb project-spec/meta-user/recipes-apps/opcua-server/`
  - python-six is broken in PL2017.4 so take fixed one and fix layer prio to 8:
    `cp ~/SoC_Workshop/Extra/python-six_1.10.0.bb project-spec/meta-user/recipes-apps/opcua-server/`
    `emacs ./project-spec/meta-user/conf/layer.conf` (change to e.g. 8)
- Step 4 – fix where the path of the quasar project is
  - `emacs ./project-spec/meta-user/recipes-apps/opcua-server/opcua-server.bb`
  - Fix SRC_URI to:
    `SRC_URI = "git:///home/pnikiel/gitProjects/SoC_Workshop_Quasar;branch=master;tag=v5"`
- Step 5 – build the PetaLinux user image (i.e. the target image) – **should take about 18 minutes**
  - `petalinux-build`
- Step 6 – package the image and stuff as bootloader binary, copy to the SD card
  - `zybo_package`
  - `zybo_cp_boot`

PetaLinux + quasar (4): PetaLinux step-by-step

- Boot the development board
- Use minicom as the console
- Connect with OPC-UA client

Part 3:

Integrating real monitoring and controls

Integrating real monitoring and controls
simple example (1)

- so far, we published switch status from from random number → we want real I/O
- generally analog digital I/O interfacing is a vary varied topic → out of scope
- I’ll use a simple GPIO library for GPIO handled by /sys/class/gpio subsystem (e.g. compatible with Xilinx GPIO driver)
  - covers few types of both PS and PL GPIOs of Zync

Integrating real monitoring and controls
simple example (2)

- I deploy the GPIO library to my project:

```
cp ~/SoC_Workshop/Switch/gpio.h Device/include/
cp ~/SoC_Workshop/Switch/gpio.cpp Device/src/
git add Device/include/gpio.h
git add Device/src/gpio.cpp
```

  and add src/gpio.cpp to CMakeLists.txt

- I know that GPIO base of Zync PS in Zybo is at 906 → I put that into a header file
- Buttons bound to Zync PS have ids of 50 (BTN4) and 51 (BTN5) → those will come via config file

Integrating real monitoring and controls
simple example (3)

- GPIO must be opened and initialize prior to use → I do it via initialize() of QuasarServer

```
if( open_gpio_channel(ZYBO_GPIO_BASE) < 0)
   throw std::runtime_error("couldnt open GPIO interface");
```

- Direction must be configured to input → I do it via Device constructor

```
set_gpio_direction(ZYBO_GPIO_BASE + config.pinId(), 1, "in" );
```

- We can finally do our readout in update():

```
int value = get_gpio_value(ZYBO_GPIO_BASE + pinId(), 1);

if (value<0)
    getAddressSpaceLink()->setNullState(OpcUa_Bad);

else

    getAddressSpaceLink()->setState(value>0, OpcUa_Good);
```

- Check if it compiles fine on laptop
- Update our config file (we added new config entry: pinId)
- If yes, commit and tag
- Rebuild the PetaLinux image and test

A note on peripheral integration

- quasar is agnostic on *how* you produce/consume sensor/actuator info
- overall we successfully built OPC-UA servers with different interfaces (CAN, SNMP, …), hardware access layers (IIO – e.g. Xilinx XADC), shared memory interfaces (VME monitoring) and so on …
- different communication patterns are supported:
  - publishing
  - read on request
  - writing, with optional delegates
  - method calls with N arguments and M return values, N and M arbitrary
- all “basic” data types are supported. Arrays are supported as well as BLOBs (“byte-strings”).

Part 4:

What about integration in the DCS systems?
(SCADA, WinCC OA)

Integration into DCS

- quasar-based OPC-UA solutions enjoy simplified integration
- WinCC OA basic concept regarding OPC-UA
  - create your DPTs (Data Point Types)
    e.g. Sensor, Crate, Branch, TriggerProcessor etc.
  - create DPs (Data Points)
    they are particular instances of DPTs, e.g.:
    Processor1/Sensor4A
  - assign so called peripheral addresses “binding” given parts of DPs to the information in your OPC-UA server
    - So you start to “see” information from your front-end or can control it
- fwQuasar is a framework for WinCC OA enabling very quick (order of minutes) integration of quasar-based monitoring and controls into DCS

Integration into DCS let's try it

- Requirements:
  - An existing WinCC OA projects with JCOP framework installed
- fwQuasar is very well documented
  (multiple entry-level developers successfully used it)
- Clone Cacophony into your OPC-UA server project:
  git clone ssh://git@gitlab.cern.ch:7999/pnikiel/cacophony.git Cacophony
- Install fwQuasar in your WinCC OA project
- Run the OPC-UA client
- Run the dialog and follow the path. Proposed settings:
  - prefix = SOC
  - server name = SOC_Server
  - subscription = SOC_Subscription
  - driver num = 69

Links, references ...

- quasar:
  https://github.com/quasar-team/quasar
  Numerous references in:
  https://github.com/quasar-team/quasar/wiki
  After cloning, see Documentation/yocto.html
- fwQuasar:
  https://gitlab.cern.ch/atlas-dcs-fwcomponents/fwQuasar
-

Backup slides

Additional ...

- C++ OPC-UA clients …
- Integration of OPC-UA servers as components in Python