Virtualization for Real-time Power Grid Substation Automation
About Seapath

SEAPATH is the result of a collaboration between 2 major european electricity players and Open source expertise.
Energy Transition drives change in power transmission and distribution grids

- Distributed renewable energy sources
- Demand response
- Electric mobility
- Smart services to the grids from a growing number of third-parties

Need to **swiftly adapt grid control architectures**

- Multiplication of distributed controls
- More dynamic and adaptive automation functions
- Increased data management needs
From where we start (digital substation)

Power Grid Substation

**SUBSTATION LEVEL**
- Monitoring
- Administration
- Automatons
- SCADA

**LAN**

**BAY LEVEL**
- SCADA
- Automatons
- Protections
- Sensors
- Digital I/O

Control Room, Maintenance, Datacenter...

High voltage
Virtualization for new grid control architecture

Implementations based on the “reference” platform from LFE project

IT integration & orchestration center

Supervision & control center

DATA CENTER

DIGITAL TWIN

Centralized App

Centralized App

Power Grid Substation

Power Grid Substation

SCADA
Monitoring
Ctrl
Prot
Prot

Integration
Test
Deployment

Supervision
Monitoring
Ctrl

SCADA
Supervision
Monitoring
Ctrl

SCADA
Monitoring
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Prot
Prot

SCADA
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SEAPATH
Software Enabled Automation Platform and Artifacts THerein
The goal of Seapath

Develop a reference design and industrial grade open source real-time platform

Host virtualized automation and protection applications

Share a platform between multi-provider applications (hardware agnostic)

Combine performance and safety
Vision & technical concept
Technical requirements

- Virtualization
- High availability
- Software Defined Network
- Cybersecurity
- Minimal services / configurations
- Low network latency
- Real-time
Let’s create our own Linux distribution without reinventing the wheel!

Existing solutions

Off-the-shelf solutions providing either

- HA & Virtualization platform
- Real-time platform
- Low-latency platform

But not a mix of that!

- Minimal firmware
- Highly configurable
The Yocto Project

Create custom Linux based systems from source code

Be agnostic of the hardware architecture

Aggregate tons of Open Source components (including Virtualization and HA)

Configure, modify each component

Check / patch Common Vulnerabilities and Exposures (CVE)

Collaborative Linux Foundation project.

Allows to:
Technical architecture and stack

**PLATFORM SERVICES**
- Platform monitoring
- Cybersecurity
- Fault detection & recovery
- Network administration
- Redundancy (cluster)

**NON-PLATFORM / THIRD PARTY SERVICES**
- Protection App
- Automation App
- OT monitoring App
- Gateway
- IEC 61850 Tools
- Real-time tests tools

**FIRMWARE**
- yocto
- Pacemaker
- ceph
- KVM
- Open vSwitch
- DPDK

**HARDWARE**
- **BEST EFFORT CPUs**
  - x86
  - x86
  - x86
  - x86

- **REAL TIME CPUs**
  - x86
  - x86

- **REAL TIME PURPOSE MEMORY**
  - RAM

- **GENERAL PURPOSE MEMORY**
  - RAM

- **PROCESS NIC**
  - NIC

- **ADMINISTRATION NIC**
Ensuring reliability
Continuous Integration

- To speed-up adopting new technologies in a critical infrastructure environment that is growing in complexity, a shift-left is needed.

- Using containerization and virtualization, combined with infrastructure-as-code enabling technologies (such as ansible) will allow automated DTAP environments.

- Early testing (fail early) in such an environment will help to create a streamlined development process.

- Such technology will limit start-up cost for new innovations, and open up the industry to newcomers.
SEAPATH CI building blocks

1. SEAPATH recipes (including docker and Virtual Machine) in github

2. Automated image build process including unit tests provided by the Yocto project

3. Automatic build pipeline and registration by Jenkins

4. Automated deployment and configuration by Ansible

5. Platform integrity tests using Cukinia

6. Integration testing of typical substation applications

7. Real-time test bench for evaluation of real-time requirements

... (interoperability testing, Site Acceptance Test, ...)
Proof of Concept
Latency checking (cyclic test): Host

**Configuration:**

**Operating system:**
Image based on yocto including KVM, Pacemaker Corosync and Ceph, Kubernetes, OvS-DPDK, Docker.

**Kernel:** 4.19 (preempt-rt and non preempt-rt)

**Hardware:**

**CPU:** 14 Core E5-2680V4  
**Memory:** 32GB DDR4  
**Circuit Board:** ASMB-8231-00A1E
Latency checking (cyclic test): Guest

**Configuration:**

**Host Operating system:**
- **Host:** see previous slide
- **Kernel:** 4.19 preempt-rt

**Guest:**
- Same as host without kvm, Ovs-DPDK
- **Kernel:** 4.19 preempt-rt
Real-time testing
SEAPATH

It will allow anyone to:

Ensure a specific set-up has the real-time characteristics suitable for its critical application in the substation.

Benchmark different hardware platforms to see if it can meet all the required performance criteria.

Understand the scale-ability potential of different setups.

Validate the real-time performance-impact of any configuration, or changes made during development and operations.
Real-time testbench

Required hardware
Measurement hardware:
PC with 2 NIC’s, 1 DPDK supported network card

Required software
MoonGen
https://github.com/emmericp/MoonGen

TestBench
https://github.com/robidev/moongen-rfc2544

Test applications
https://github.com/seapath/meta-seapath-tools

Output
Report of performance measurements, “inspired” by RFC2544
RFC 2544 Test Report

1 General Test Information
Device Under Test: KERNEL
Operating System: vostp
Date: 2021-03-22

2 Throughput
Test Duration: 1 s
Maximal Loss Rate: 10.000 %
Accuracy: 100 Mbps

3 Latency
Test Duration: 1 s

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Call to Arms

Desired contributions:

• We need end user feedback!
• End user applications
• Feedback regarding the platform's features (do we miss any?)
• Test bench validation, and checks for completeness

https://github.com/seapath/
Thank you for your attention

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