Reconfigurable Communication Processor for Future Smart and Connected Community Network

Satoru Okamoto, Naoaki Yamanaka, Chiaki Hara, and Naoto Sumita: Keio University, Japan
Takayuki Muranaka: Alaxala Networks, Japan
What’s Alaxala Networks?

Alaxala Networks is one of Japan’s leading vendors of Routers/Switches.

- **Establishment**: October, 2004
- **Location**: Kawasaki, Kanagawa, Japan
- **Business**: Development, manufacturing, sales, maintenance of Routers/Switches for mission critical network

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**The Guaranteed Network**

Closer to you, Further into the future.

Layer 2 switches
(AX2130S, AX2530S)

Layer 3 switches
(AX4630S, AX3660S)

Core and edge routers
(AX8600R)
Outline

- Background
  - Smart and Connect Community (S&CC)

- Network Infrastructure for supporting S&CC
  - Computing
  - Networking
    - Photonic Network Processor
    - Reconfigurable Communication Processor (RCP)

- Application examples of RCP networks
Multi-service and huge traffic demand by Smart & Connected Community

CPS : Cyber-Physical System
Background for Smart & Connected Community (S&CC)

- **Heavy traffic demand**
  - Video traffic (4K, 8K) requires over 100 Gbit/s interface (Beyond 100G IF)

- **Service diversity**
  - From over 100 Gbit/s video and several bit/hr IoT sensors are connected

- **Dynamic and Mobility**
  - Autonomous Driving Vehicle (ADV) and Machine to Machine (M2M) are new demand

- Node and Network architecture have to meet those requirements.
- Collaboration of Computing and Networking becomes more important.
There is no device which supports both beyond 100 G class processing capacity and flexibility.
Some Key Words

- **Wide Dynamic Range**
  - Several bit/hour to over 100 Gb/s

- **Support high speed wire-rate processing with flexible configuration**
  - Not only the software processing but also the hardware processing
    - Co-design with software and hardware

- **In-network processing and Resource Pool**
  - A network provides not only the networking function but also the computing function
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Function modules are interconnected by BUS

S-100 SYSTEM
A typical mainframe S-100 system equipped with:
(1) A CPU board
(2) Two RAM boards
(3) A floppy drives controller board
(4) An I/O board.

Source: http://www.old-computers.com/museum/photos.asp?t=1&c=410&st=1
160 TB shared memory over 40 nodes

Architecture of The Machine

Special purpose cores = Processor pool
Photonics = Network
Massive memory pool

SoC:
- Local DRAM
- NVM

Physical Server

Network = BUS

SoC: System on Chip
NVM: Non-volatile Memory

Resource Pool

- Resource Pool is commonly used in the computing world

- The system is dis-aggregated to each function module

- Cloud, Virtualization, and Resource Slicing
Layer 1 (and 0)
- SDH, WDM, OTN, and ROADM
  - longer transmission distance and larger capacity

Layer 1+2 Integration
- Packet Optical Node

Management/Control/Data Separation
- Unified Control = Generalized Multi-protocol Label Switching (GMPLS), Transport Software-defined Networking (T-SDN), etc.

Software-Defined, Application Driven
- Architecture on Demand (AoD) node
- Unified Control
- Scalable Node

Disaggregation
Resource Pool
Whitebox
Approach in early 21st century:

- NTT’s “Hikari-Router (SWAT architecture)”

- Large capacity IP router will be constructed with many L1, L2, and L3 modules.
- Generalized Multi-Protocol Label Switching (GMPLS) was applied for “Unified Control”.

2010 era:

Architecture on Demand (AoD)

- 1st Proposed for L1 optical node architecture.
  - Now, L2 and L3 can be applicable → “Application on Demand”
- Improvement of Reconfigurability → “Software-Defined”


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**b) Example architecture**


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Concept of “Photonic Network Processor” has proposed in 2014

- “Photonic Network Vision 2020 – Toward Smart Photonic Cloud”
  - Synthetic Photonic Node, Photonic Network Processor, and Smart Photonic Software-defined Networking
Si-photonic inter-chip connection on Photonic Interposer

Y. Urino et al., ECOC2013, Mo.4.B.2.
Photonic Interposer is an immature technology

Metal lines

CMOS interposer (NoC)

Photonic interposer (Silicon Photonics)

WDM inter-board IF

<table>
<thead>
<tr>
<th>Technology</th>
<th>Metallic</th>
<th>Active</th>
<th>Photonic</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-chip bandwidth</td>
<td>≤ 250 Gb/s</td>
<td>≤2 Tb/s</td>
<td>&gt;4 Tb/s (&gt;2x)</td>
</tr>
<tr>
<td>Number of cores</td>
<td>≤ 16</td>
<td>≤ 36</td>
<td>&gt; 72 (&gt;2x)</td>
</tr>
<tr>
<td>Power for on-chip</td>
<td>~ 1 W</td>
<td>~ 20 W</td>
<td>~ 20 W (~1x)</td>
</tr>
</tbody>
</table>

Both high-speed processing and flexibility!!

Co-design of LSI/FPGA/NP/CPU is required

<table>
<thead>
<tr>
<th>Device</th>
<th>LSI</th>
<th>FPGA</th>
<th>NP</th>
<th>CPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packet processing (single chip)</td>
<td>Over 100 Gbps</td>
<td>few 10s to 100 Gbps</td>
<td>few 10s to 100 Gbps</td>
<td>10 to few 10s Gbps</td>
</tr>
<tr>
<td>Power consumption per processing capacity</td>
<td>Very low</td>
<td>Low</td>
<td>Middle</td>
<td>High</td>
</tr>
<tr>
<td>Processing unit</td>
<td>Hard-wired processing + Processing definition table</td>
<td>Hard-wired processing + Processing definition table</td>
<td>Processor + Hard-wired processing</td>
<td>General purpose processor</td>
</tr>
<tr>
<td>Supported functions</td>
<td>Layer 1 to 4</td>
<td>Layer 1 to 4</td>
<td>Layer 1 to 4 + Service layer</td>
<td>Layer 1 to 4 + Service layer</td>
</tr>
<tr>
<td>Programmability</td>
<td>Low (Processing definition table)</td>
<td>High (reconfiguration)</td>
<td>Very high (software)</td>
<td>Very high (software)</td>
</tr>
<tr>
<td>Performance guarantee</td>
<td>Guaranteed</td>
<td>Guaranteed</td>
<td>No (some processing can be guaranteed)</td>
<td>No (few processing can be guaranteed)</td>
</tr>
</tbody>
</table>
Resource Pool Architecture based on Reconfigurable Communication Processor (RCP)

RCP consists of a Reconfigurable Processing Module (RPM)*1, Reconfigurable Service Module (RSM)*2, and Tbps class (electrical packet) switching module interconnecting them.

- RPM corresponding to multiple communication protocols
- RSM providing various functions

Multiple service Slices Can be provided

*1,2 Alaxala Networks is developing RPM (Reconfigurable Processing Module) and RSM (Reconfigurable Service Module) targeting 2020.
How to scale out by X-bar switch

- Co-designing LSI, FPGA, and NP enables 400Gbps class reconfigurable intelligent D-plane
- Flexible and scalable architecture based on Resource Pool connected via "Virtual X-bar"
RCP’s “Resource Pool” Router architecture

1. Base board
2. Daughter board
3. Resource pool Router as RCP

Pool of interconnects
Pool of LSIs and FPGAs
Pool of NP/CPUs

Beyond 100G class interface
Beyond 100G class interface
Beyond 100G class interface
Beyond 100G class interface
Beyond 100G class interface

Flexible Channelized link
Physical Link
Physical Link
Physical Link
Physical Link

Logical Channelized link
Logical Channelized link
Logical Channelized link
Logical Channelized link
Logical Channelized link

RPM: Reconfigurable Processing Module
RSM: Reconfigurable Service Module

RCP: Reconfigurable Communication Processor

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Resource pool architecture is realized by **flexible reconfigurable nodes in the optical network**. It accommodates flexible network services (service slices) and enables flexible network construction.
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Multi-access Edge Computing (MEC) is a key application architecture of S&CC network.

- **Industrial Robot Control**
  - VM Migration according to latency, computation performance, number of requests/users, etc.
  - Optically-connected Dynamic Sliced Local Resource Cluster (ODSLRC)
  - Edge Computers (EC)
  - Local/real-time control

- **Autonomous Driving Vehicle (ADV) Control**
  - Low-latency ADV Control e.g. Alert Messaging for Non-motorized Individuals

- **Elastic Optical Metro/Access Network**
  - + 5G Wireless Access Network
  - Cloud DC
  - Local DC
  - 5G Base Stations
  - LTE Device
  - LPWA (LTE-M)
  - LR-WPAN
  - ADVs

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Elastic Optical Metro/Access Network + 5G Wireless Access Network

- Virtual Machine for Robotics
- Local DC
- Global/high-load computation
- Cloud DC
Dynamic VM migration for autonomous driving vehicles: OpenStack on RSMs

Local control
Calculate steering angle, accelerator value, etc.

Edge control
Decision making and path control

Cloud control
Higher Level application like traffic control between edges

VM

Edge VM live migration

Main targets of experiment are …

- Add computing resources to the cloud and execute applications for autonomous driving.
- Migrating across two layers using computing resources on PROnet.
Multi-protocol Reconfiguration by RPMs

- 2 RCPs are located in NICT Tokyo, Japan and SC18 NICT booth at Dallas, USA
- Dynamically reconfigured with few seconds service down time
RPMs are configured as “Mirroring” and “FlexCounter”.

NICT’s NIRVANA-kai is applied to visualize the flows in the 100GE link identified by countries.

- If only 1 RCP is used, half of flows can be visualized.
  - Because num. of ACL entries is not enough.
- If 2 RCPs are used, all flows can be visualized.
  - Applicability of the resource pool concept.
Random forest can be applied to ML-based DDoS detection.

RSM pool can be used as distributed scalable random forest executing platform (e.g. Hadoop on RSMs).

Ref. N. Sumita, et al., iPOP2019 P-3, May 2019
“Resource pool” and “Multi-access Edge Computing” are the keys to create services in Smart and Connected Community.

Reconfigurable Communication Processor (RCP) is now developing under the Reconfigurable Packet λ project.

- Alaxala Networks will provide RCP which has 400 Gbps IF.
- Keio University will provide vRCP resource control and management.
- RCP applications are testing and demonstrated.
This work is partly supported by the reconfigurable packet-lambda project funded by the National Institute of Information and Communications Technology (NICT) Japan, JSPS KAKENHI Grant Number JP17H03269, and JGN-A18002.