



Data-Centric Infrastructure (DCI) with Photonics for IOWN

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Background

- Why we need IOWN technology for energy efficiency?
- IOWN ... The World Aimed at by “Photonics-Electronics Convergence (PEC) Technology”

Photonics-Electronics Convergence (PEC) changes computers ... DCI

- Photonics-Electronics Convergence device for reducing power consumption in high-speed communication
- Architectural Proposals for High-Speed Optical I/O ... DCI using PEC
- Power saving effect of the proposed configuration

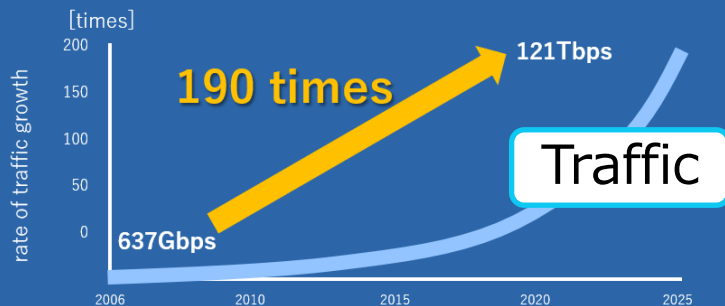
Image of future DCI using PEC-3

Summary

Growing Traffics and Power consumption

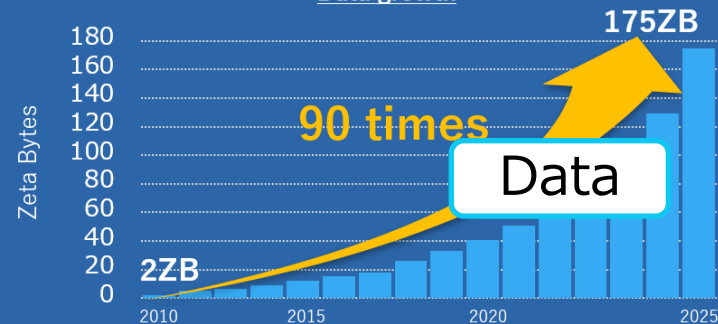


Estimating the amount of information distributed through the Internet



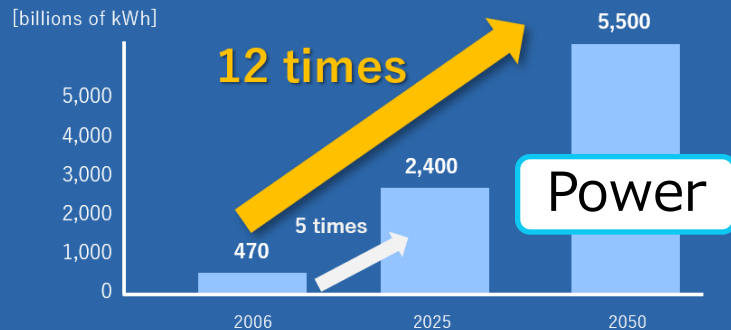
Source: "Green IT Initiative" (2007.12) by the Ministry of Economy, Trade and Industry

Data growth



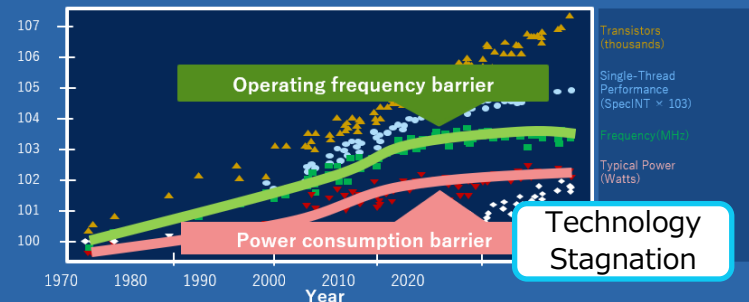
Source: IDC "November 2018 The Digitization of the World From Edge to Core"
The Digitization of the World from Edge to Core, November 2018

Estimation of IT equipment power consumption



Source: "Green IT Initiative" (2007.12) by the Ministry of Economy, Trade and Industry

Stagnation in technological evolution



Original data up to year 2010 collected and plotted by M.Horowitz, F.Labonte, O.Shacham, K.Olukotun, L.Hammond, and C.Batten. New plot and data collected for 2010-2017 by K.Rupp

Source: <https://www.karlsruhp.net/2018/02/42-years-of-microprocessor-trend-data/>

NTT Group's New Environment and Energy Vision

"NTT Green Innovation toward 2040"

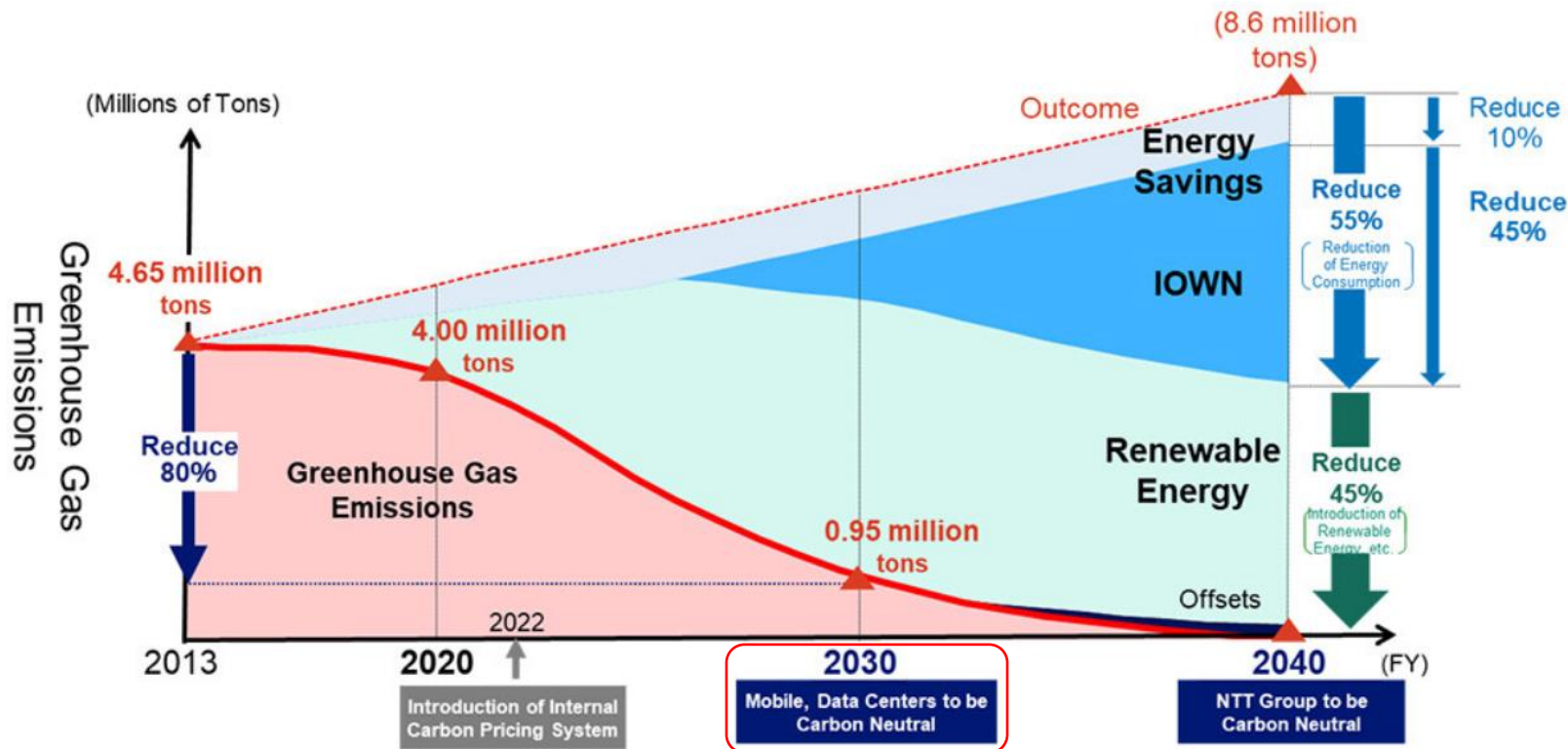
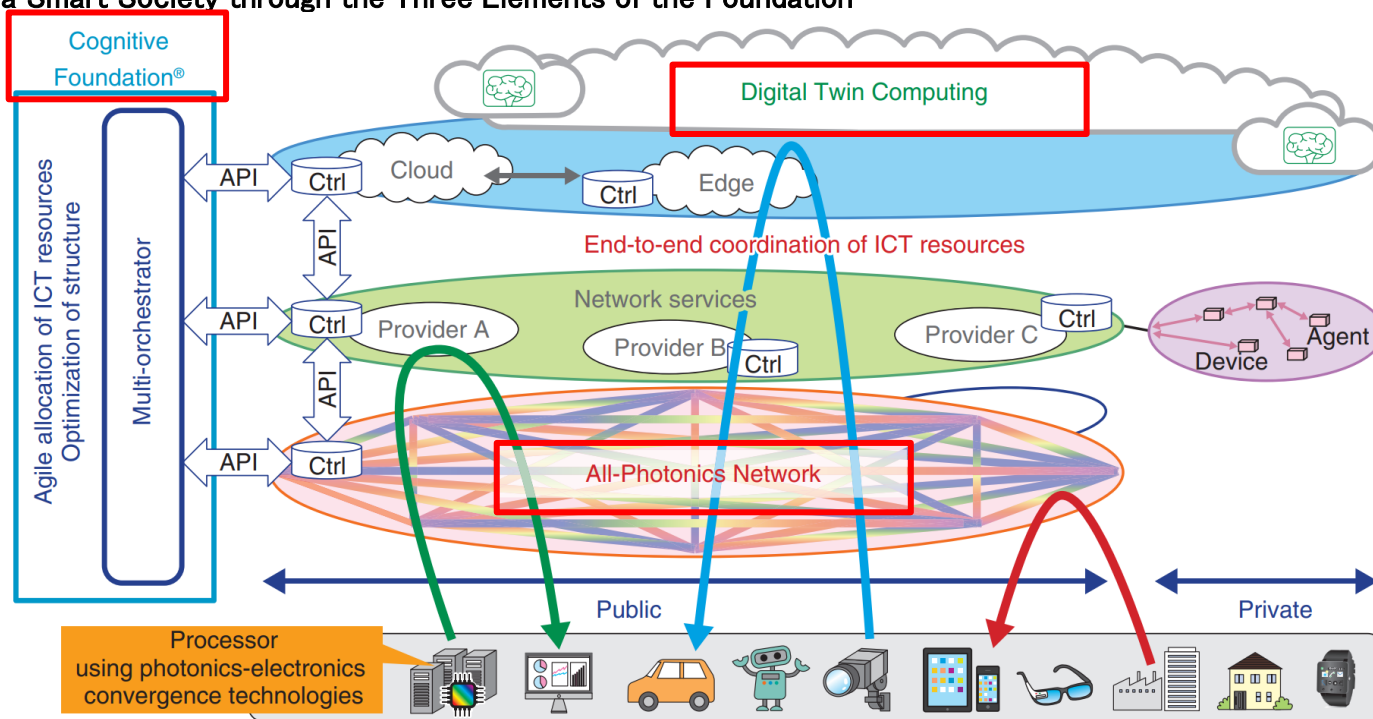


Figure 1 Illustration of NTT Group greenhouse gas emission reductions (domestic and overseas)

What is IOWN?

Concept of Innovative Optical and Wireless Network(IOWN)

All Photonics Networks, Digital Twin Computing, Cognitive
Creating a Smart Society through the Three Elements of the Foundation



API: application programming interface

Ctrl: controller

ICT: information and communication technology

Key Technology for IOWN: Photonics-Electronics Convergence (PEC) Devices

“Transmitting”
by Photonics Technology



“Processing”
by Electronics Technology

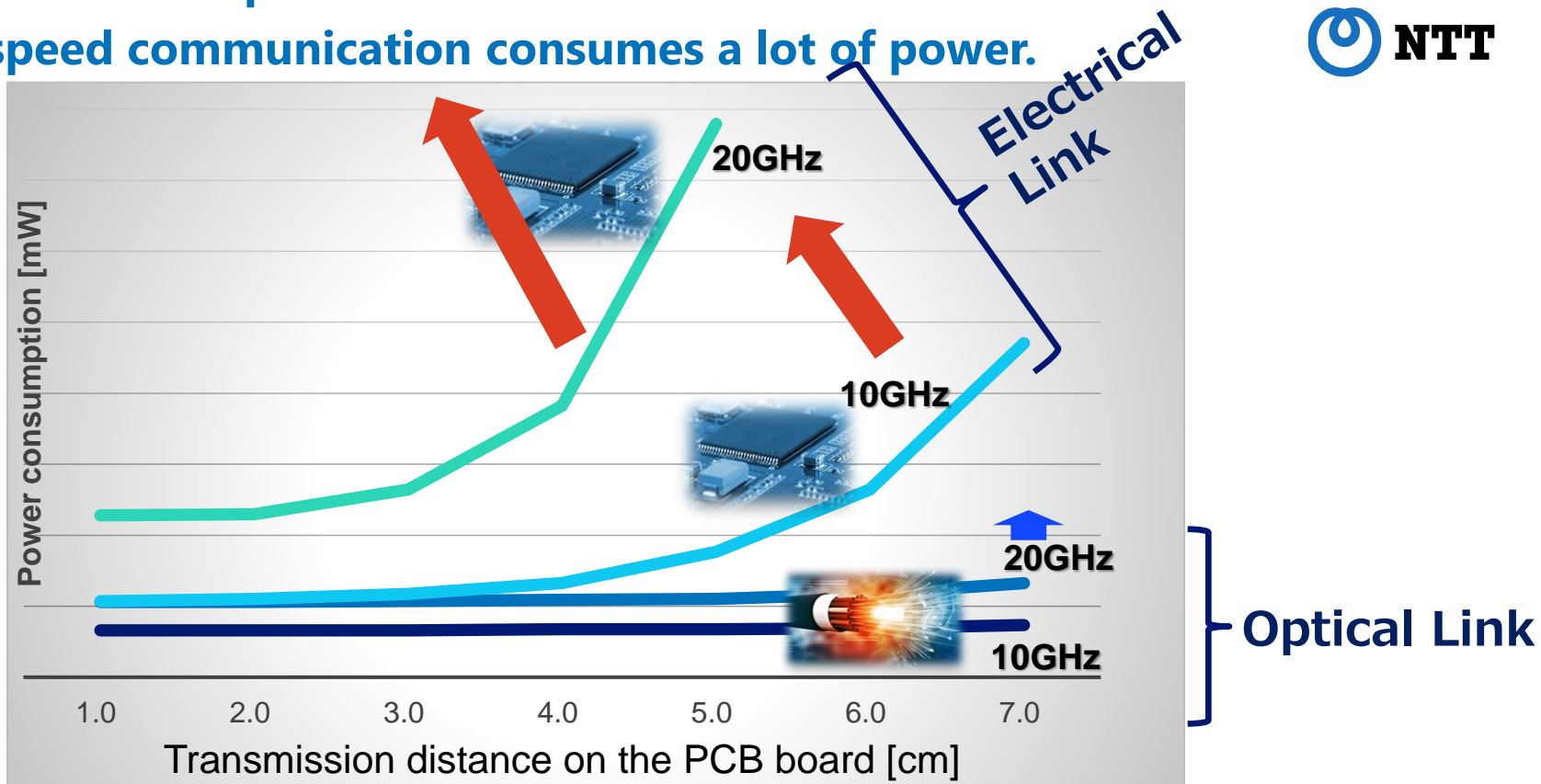


**Combination of photonics & electronics
for next gen networking and computing**

**“Photonics-Electronics
Convergence”**

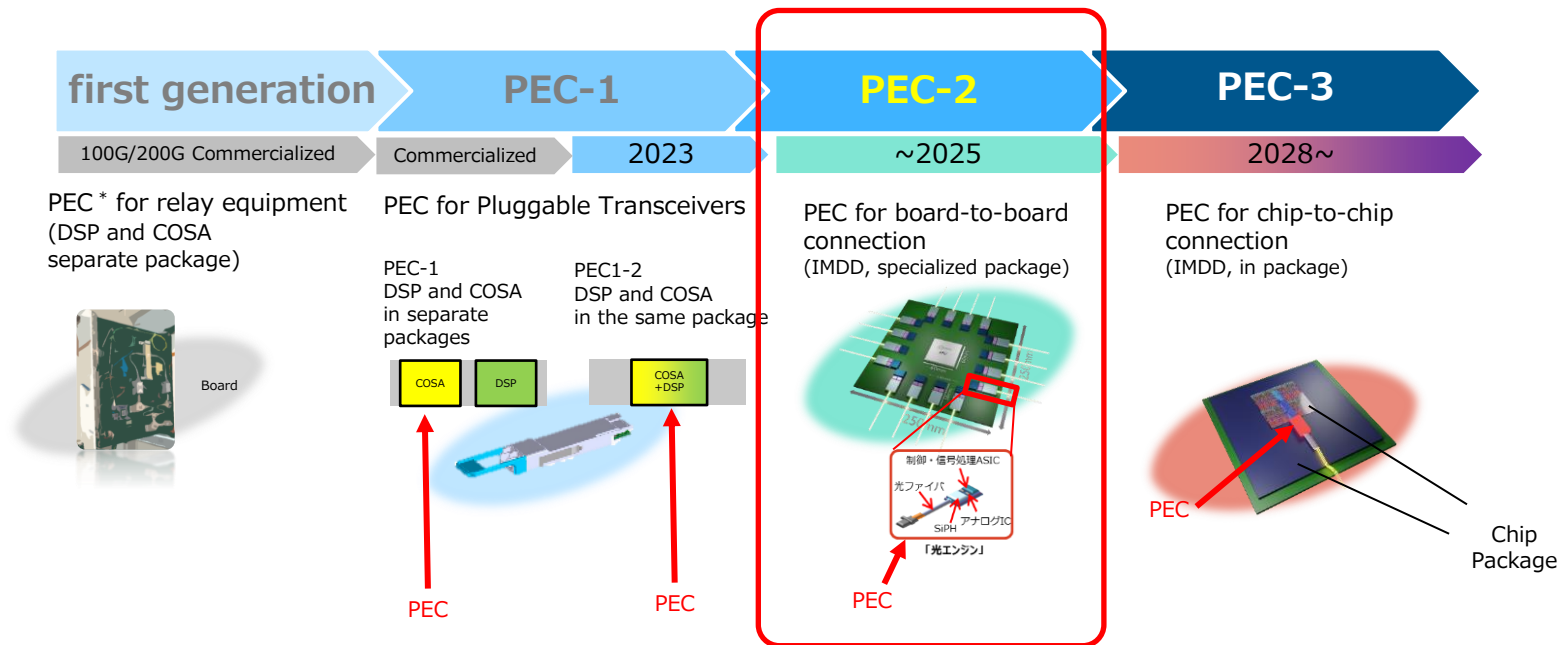
Electric link v.s. Optical link

High-speed communication consumes a lot of power.



Optical Link is the essential piece of making lower power, higher performance and longer distance.

R&D Roadmap for Photonics-Electronics Convergence (PEC) Devices



※PEC...Photonics-Electronics Convergence
COSA...Coherent Optical Sub-Assembly
DSP...Digital Signal Processor
IMDD ... Intensity-Modulation Direct-Detection

Computer Using Photonics-Electronics Convergence Devices NTT

- Optical NWs have already been installed into DCs and HPCs. With this flow, optical NWs will be employed between cores and installed even into chip.
- NTT has already demonstrated calculation of optical line rate by using the optical NW. NTT believed this also will move to short range NW.

Photonics connects **computers**

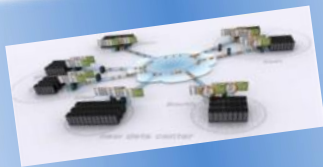


Photonics connects **devices in computers**

As the data rate is increases, the applicable distance of optical link is getting shorter



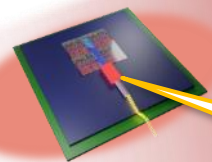
Long-haul



Inter-datacenter
(< 120 km)



Intra-datacenter
(< 2 km)



Inter-chip
(m - cm)



Intra-chip

photonics-electronics
convergence device
(**PEC device**)

Computer architecture needs to be changed to be suitable for photonics.



Data-Centric Computing (DCI) with Photonics 8

IOWN Global Forum DCI Overall Architecture



Photonics-Electronics Convergence
changes computing (DCI) and
communications (APN)

Overall Architecture

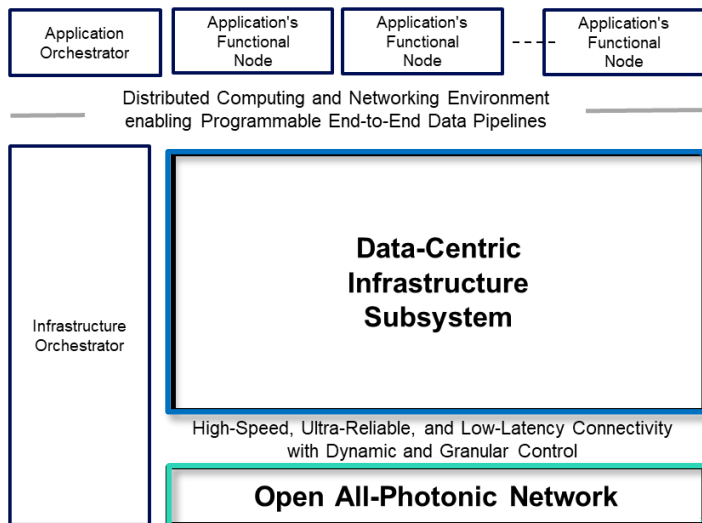
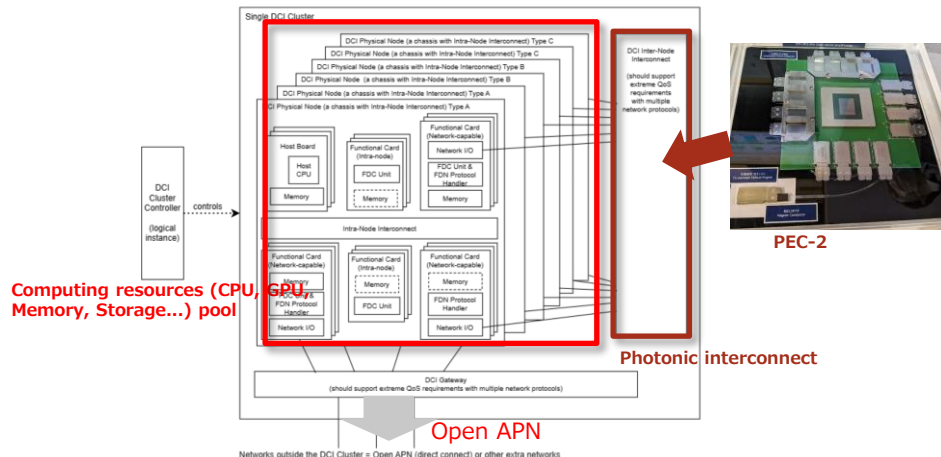


Figure 3.1-1 : IOWN Overall Architecture

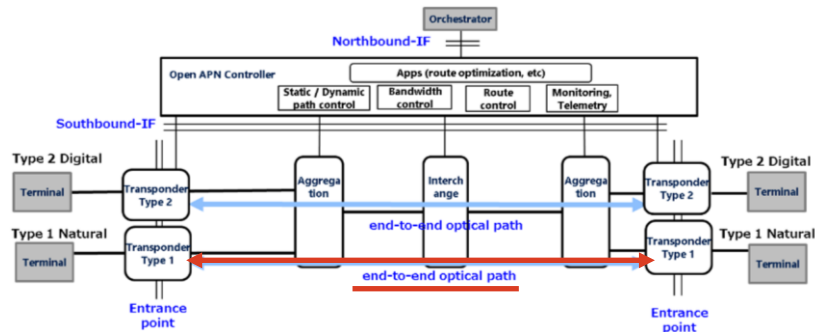
https://iowngf.org/wp-content/uploads/formidable/21/IOWN-GF-RD-System_and_Technology_Outlook_1.0-1.pdf

https://iowngf.org/wp-content/uploads/2023/04/IOWN-GF-RD-DCI_Functional_Architecture-2.0.pdf

DCI (Data-Centric Infrastructure) provides computing resources



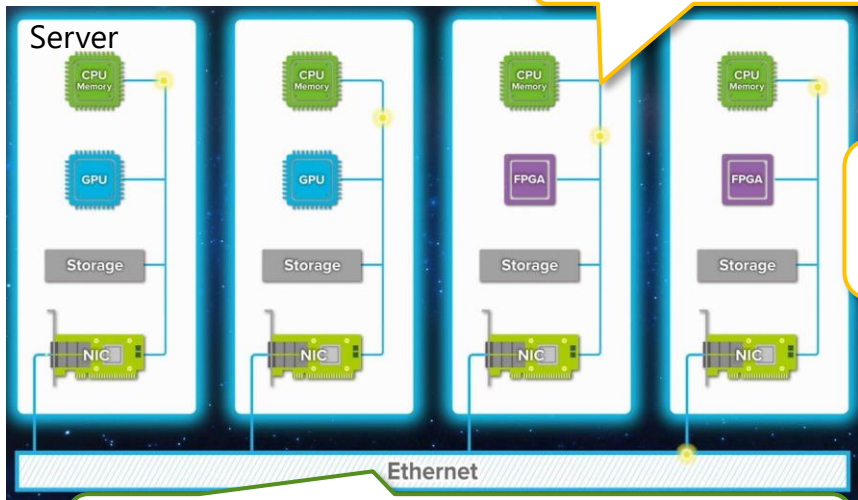
APN (All-Photonic Network) provides end-to-end optical path



Concept of DCI with Photonics for IOWN

- Use Photonics-electronics convergence (PEC) devices for maximizing the power efficiency of computing servers.

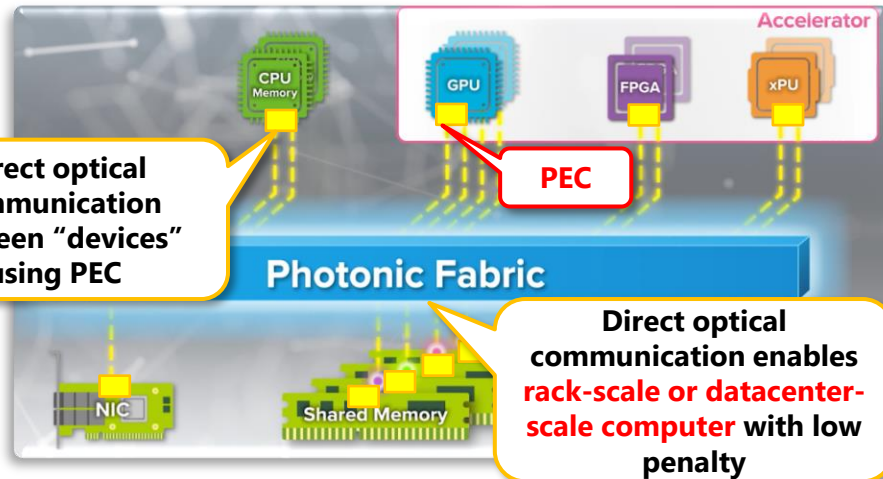
Conventional architecture



TCP/IP over Ether External Network
Large latency, Limited bandwidth, Additional processing time for packet processing ,..etc.

- Each "Chassis" is the granularity of expansion.
- Internal "box" is optimized for each, but some penalty for multiple stack for large computing.

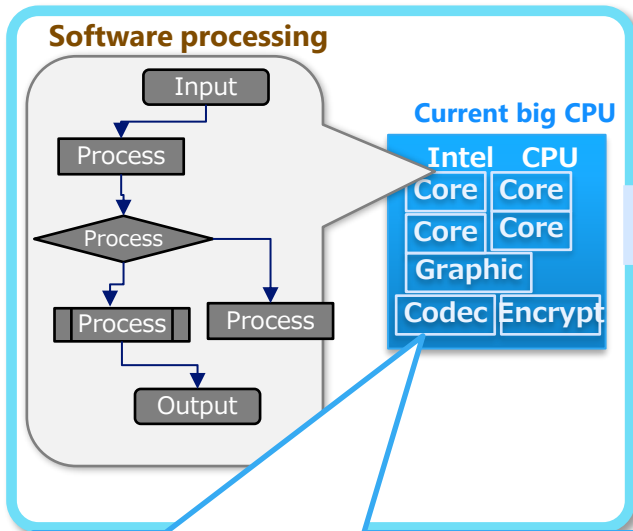
DCI with Photonics



1. Each "device" is the granularity of expansion.
2. "Devices" are interconnected by large bandwidth, low latency optical communications.
3. CPU processes are largely off-loaded to multiple accelerators, the necessary process for CPU is mainly to decide computing flows.

Program optimization for DCI

Conventional architecture

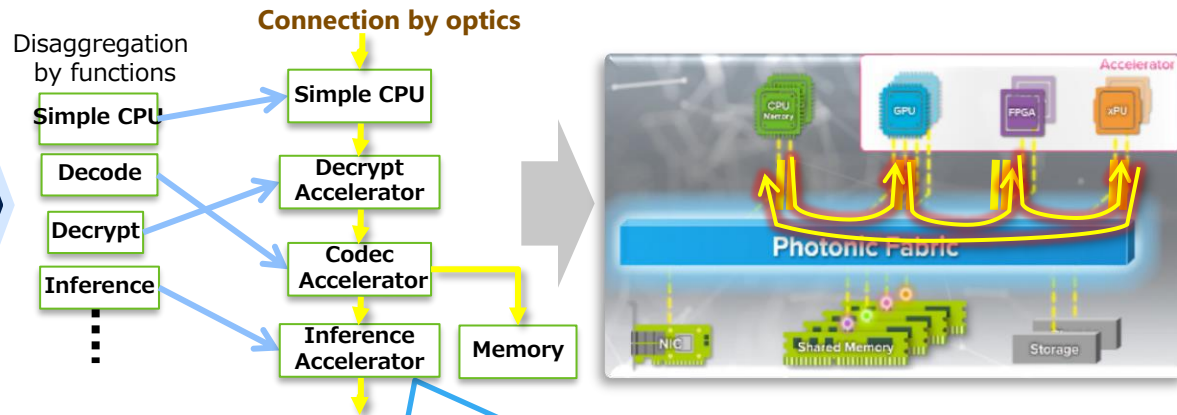


CPU centric

CPU communication penalty with outside of the chip is very large.

To avoid communication penalties, almost all processes should be done by software within the CPU core.

DCI with Photonics



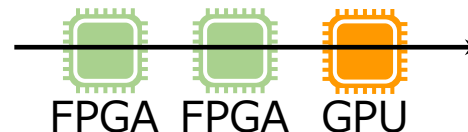
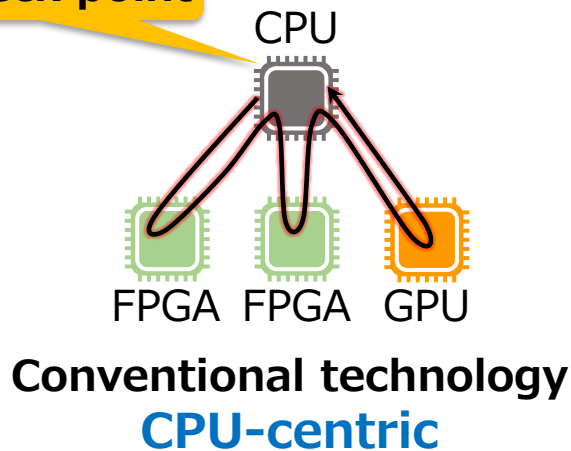
Processing by multiple accelerators
Fat pipe by optical communication enables combined use of appropriate accelerators, with low penalty and high power efficiency

e.g. GPUs are more faster and power efficient than CPUs

DCI Direct communication between processors

Autonomous communication by dedicated processors enables data transfer without involving CPUs, realizing a new computing paradigm based on dedicated processors.

Bottleneck point

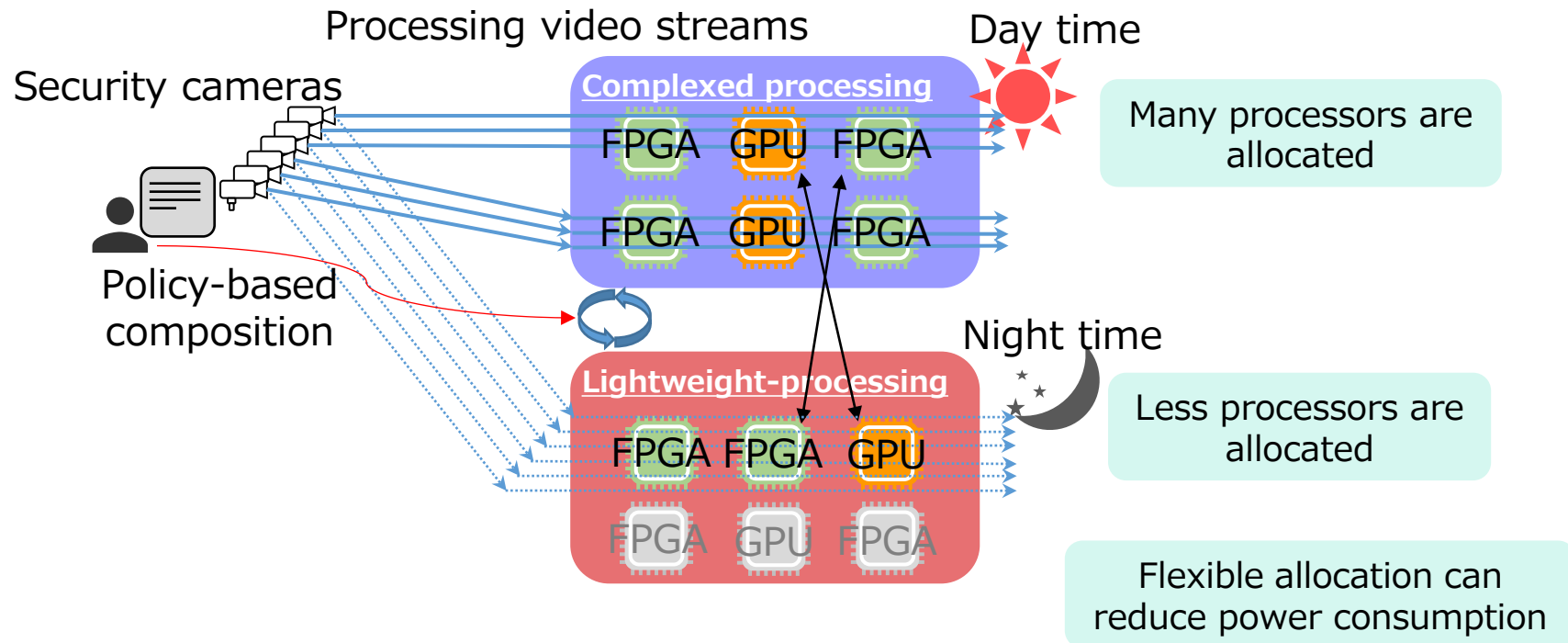


**Direct communication between
dedicated processors
(accelerators)**

DCI Flexible reconfiguration of dedicated processors



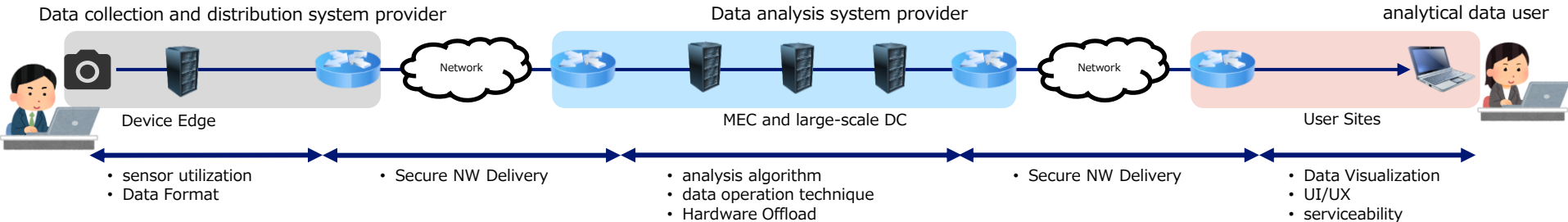
Optimal composition of dedicated processors according to application and scene.



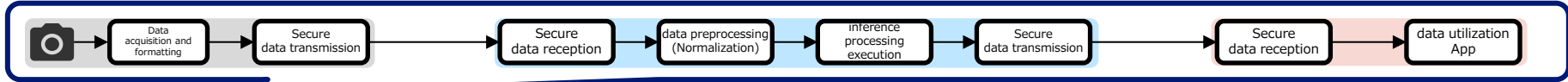
DCI controller technology



DCI Controller software will help users to automate resource allocation.



Defined by abstract functional blocks



creation instruction

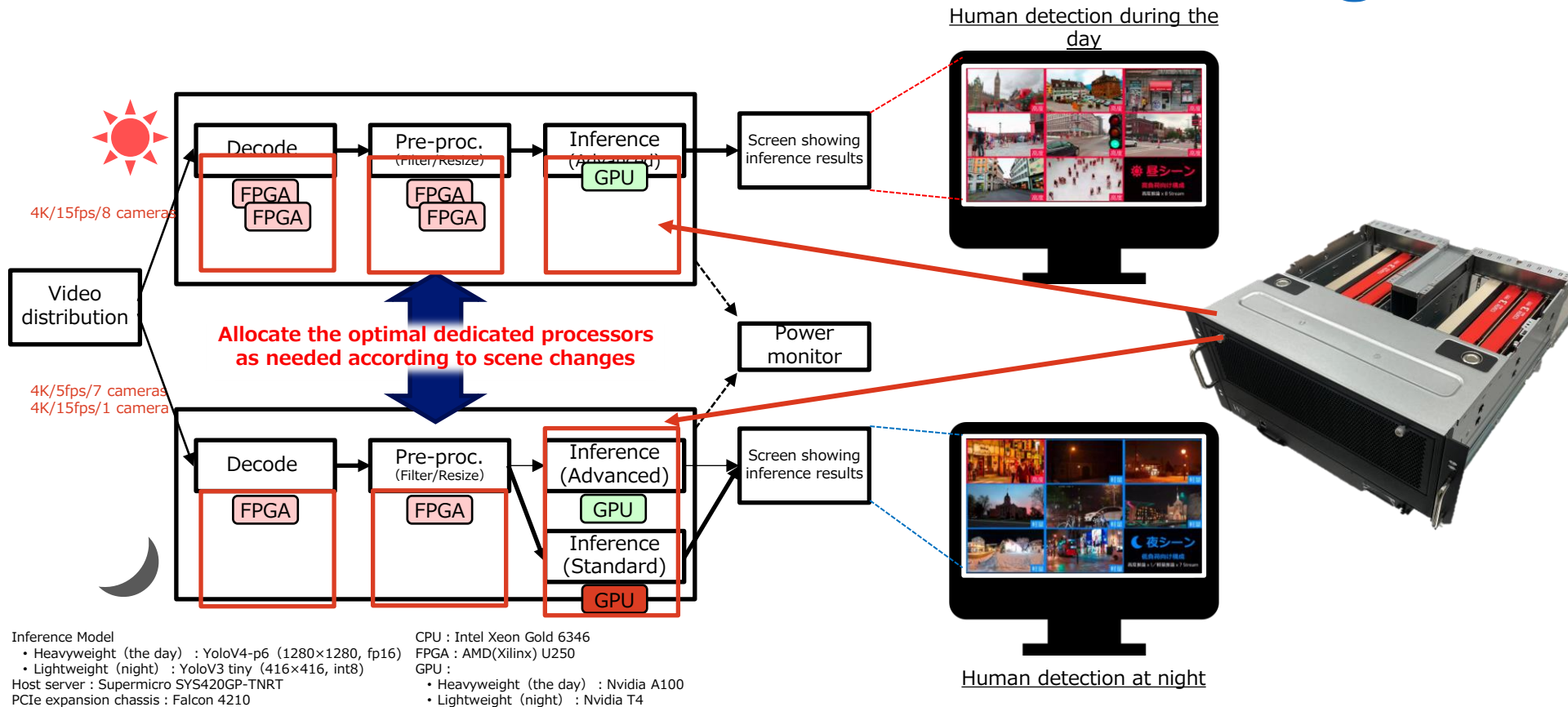
DCI Controller

Process Catalog Lookup

functional deployment

Function	arithmetic unit	Processing method
preprocessing	FPGA	smoothing
inference processing	GPU	Yolo v4 (Object Detection)
Secure Send	FPGA	vGW Service
...

Prototype evaluation



Prototype evaluation result



Human detection during the day

高度推論 x 8 Stream

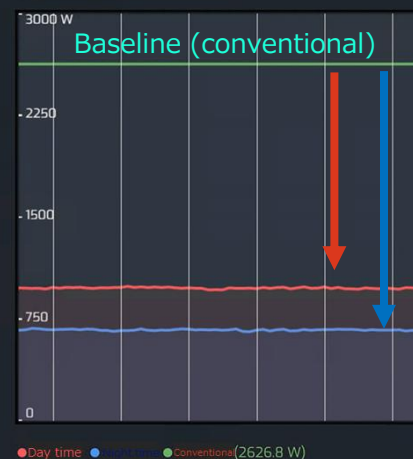
Super White Box Demo

Demonstration of optimal accelerator deployment and power reduction during the day and night

☀ Human detection during the day



⬇ Power consumption



Day time

977.1
W

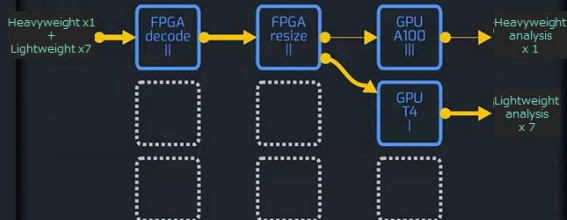
Reduction
62.8
%

Night time

669.1
W

Reduction
74.5
%

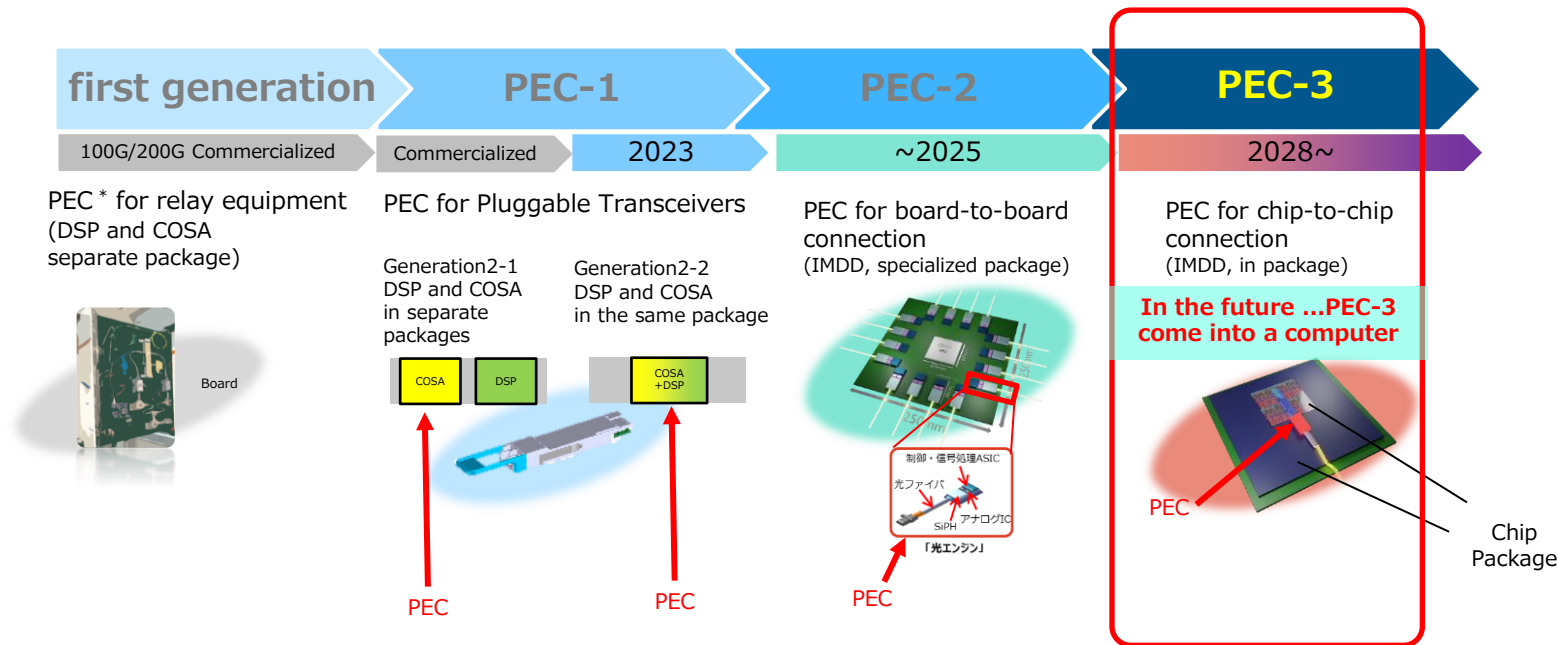
☾ Human detection at night



Human detection at night

高度推論 x 1 / 軽量推論 x 7 Stream

R&D Roadmap for Photonics-Electronics Convergence (PEC) Devices

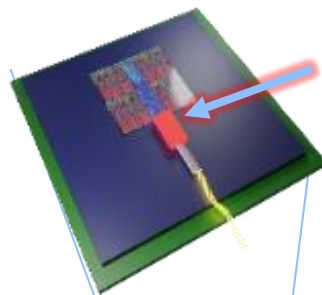


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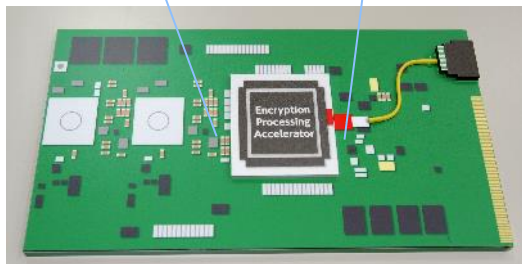
Image of future DCI using PEC-3

Compact, high-density
Photonics-Electronics Convergence device (PEC-3)
is installed close to the LSI die.

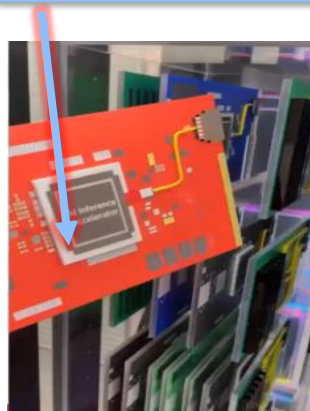
- Miniaturization and higher density make devices closer to LSIs
Shorten the electrical transmission distance as much as possible.
=> Realization of wider bandwidth and lower power consumption



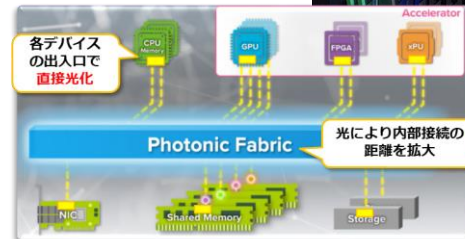
PEC-3
(Photonics-Electronics
Convergence Device 3)



Realizing the rack scale computers by
Direct optical connection between cards and components



光ディスクアグリゲータッドコンピュータ



- Introduced IOWN technology for improving energy efficiency.
- Data-Centric Infrastructure (DCI) with Photonics has been proposed as a technology using Photonics-Electronics Convergence (PEC) technology.
- Prototype evaluation results gets 74.5% and 62.8% in power consumption reduction. (at low-workload and the busy-workload respectively.)
- In the future DCI, PEC-3 will be adapted to DCI. It can realize rack-scale computers (DCI with PEC-3). DCI with PEC-3 will get further energy efficiency and further flexibility of configuration.

Your Value Partner