Normally-Off MCU Architecture for Low-power Sensor Node

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Masanori Hayashikoshi (Speaker),
Yohei Sato,
Hiroshi Ueki,
Hiroyuki Kawai,
Toru Shimizu,
Renesas Electronics Corporation

Outline

- Introduction
- Lower power requirements of sensor nodes in smart society
- Challenges for low-power sensor node
- Proposal for normally-off architecture for low-power sensor node
- Summary and Conclusions

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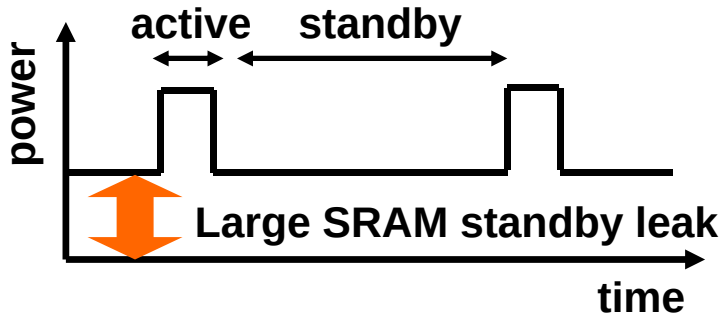
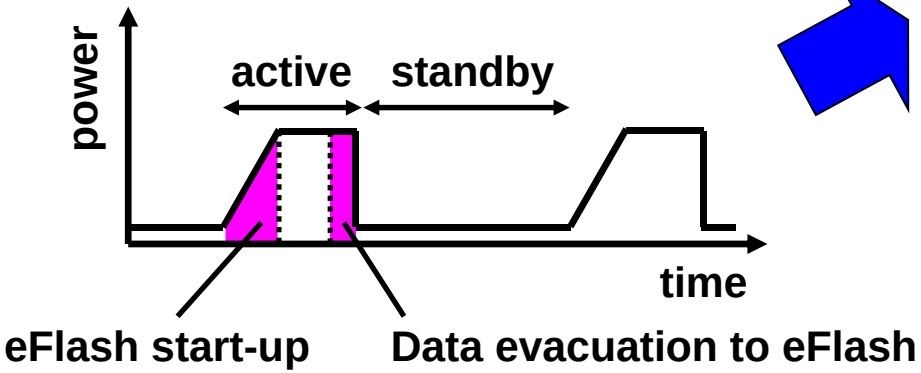
Paradigm shift for power savings

- Intermittent system operation by NVRAM will be a promising solution to low-power requirements.

SRAM based operation

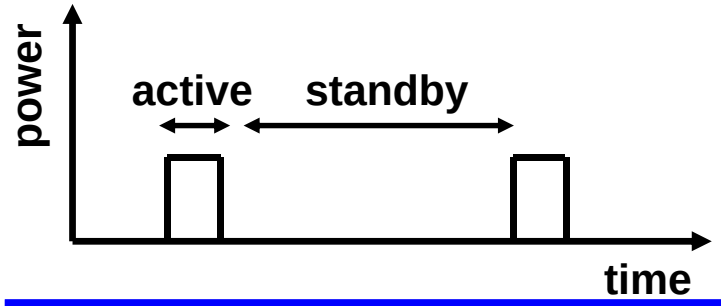


eFlash based operation



NVRAM based operation

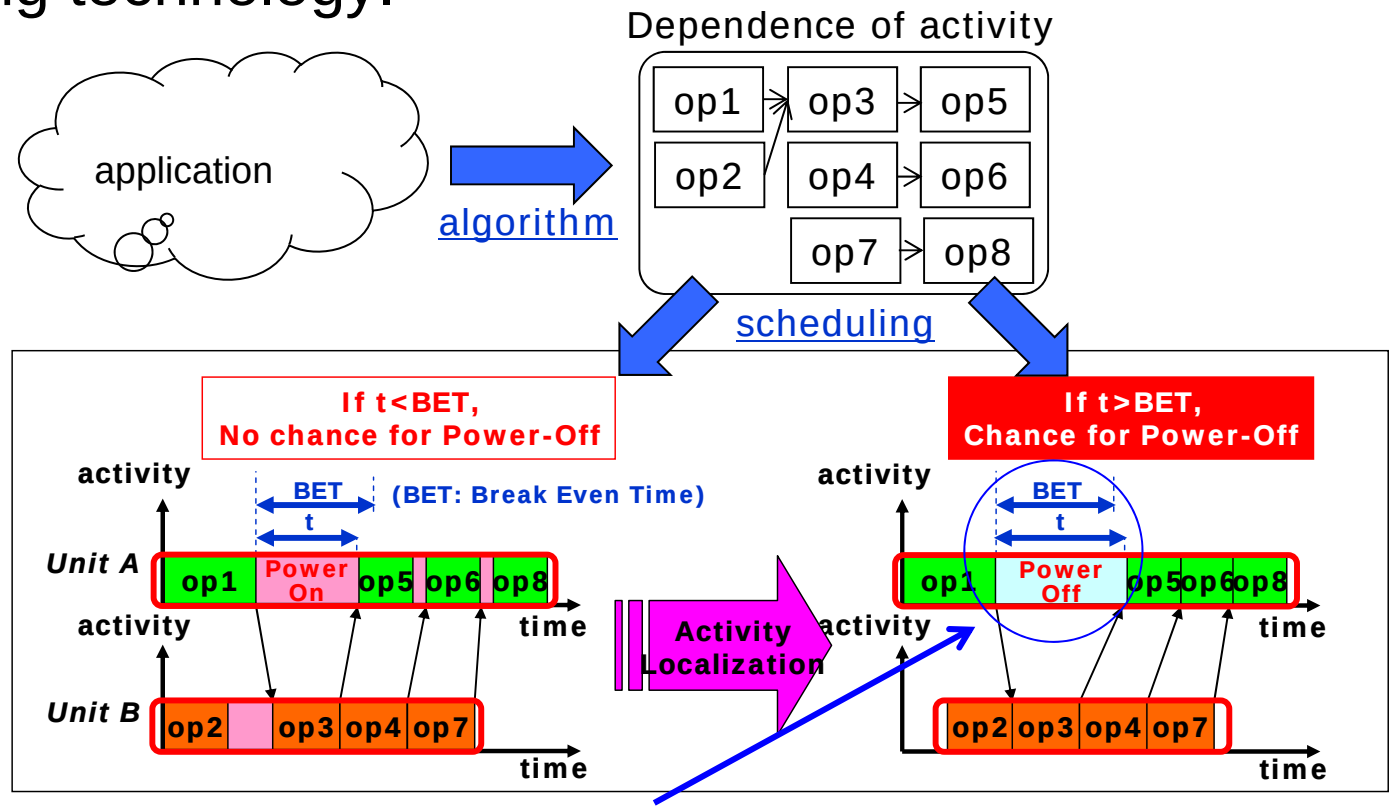
<Features>
- Fast power-on/off
- No DC current during standby



<Advantages>
- Very low power consumption
- Reliability improvement of Trs in peripheral circuits

Challenge for further power saving in NVRAM system application

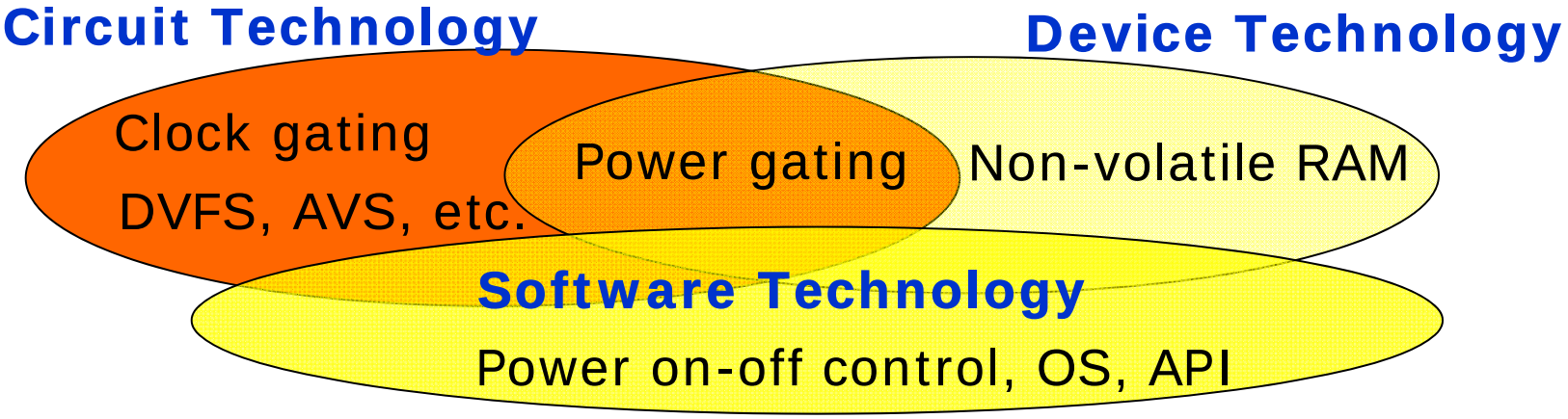
- "Normally-off computing technology" is enable to cut off the power, except for the component in work truly even in operation as a system, with synergy of NVRAM and power gating technology.



Maximize the power-off period with activity localization

Technologies to realize “Normally-Off Computing”

- Power-Off as long as possible, as large area as possible, if QOS is satisfied.
- Power-Off during IDLE-Time of circuits, function blocks, chips, units and systems.
- Application-independent Computing Platform based on Power-gating, Software-control and OS API.



➡ “Normally-Off Computing” is a System-level platform technology with combining HW and SW technologies.

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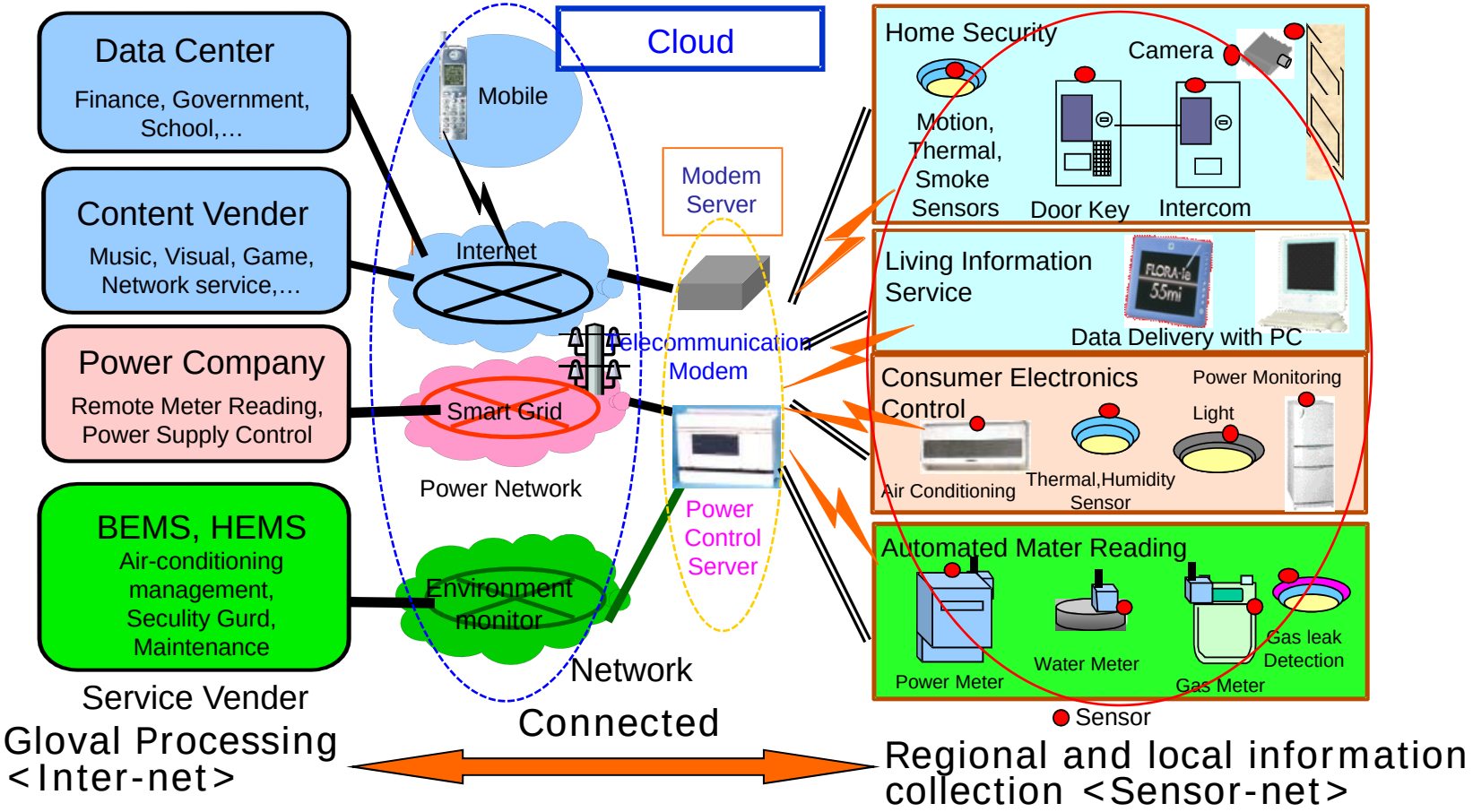
Cyber-Physical System is a fundamental technology in Smart City

- The advanced service can be realized with collecting real-time information in the social and natural environments.



Therefore, sensor nodes become used extensively to gather the real-time information.

Production volume of Sensor Node

- Production Volume: ~10B pcs/year
- This volume will be much increased with the development of cyber-physical systems.

➡ It becomes very important how to reduce the power consumption of huge sensor nodes.

PC & Server	Mobile Phone & Terminal	Embedded Sensor-node
		
0.3B pcs/year	1.5B pcs/year	10B pcs/year

(Production Volume: 2011 Data)

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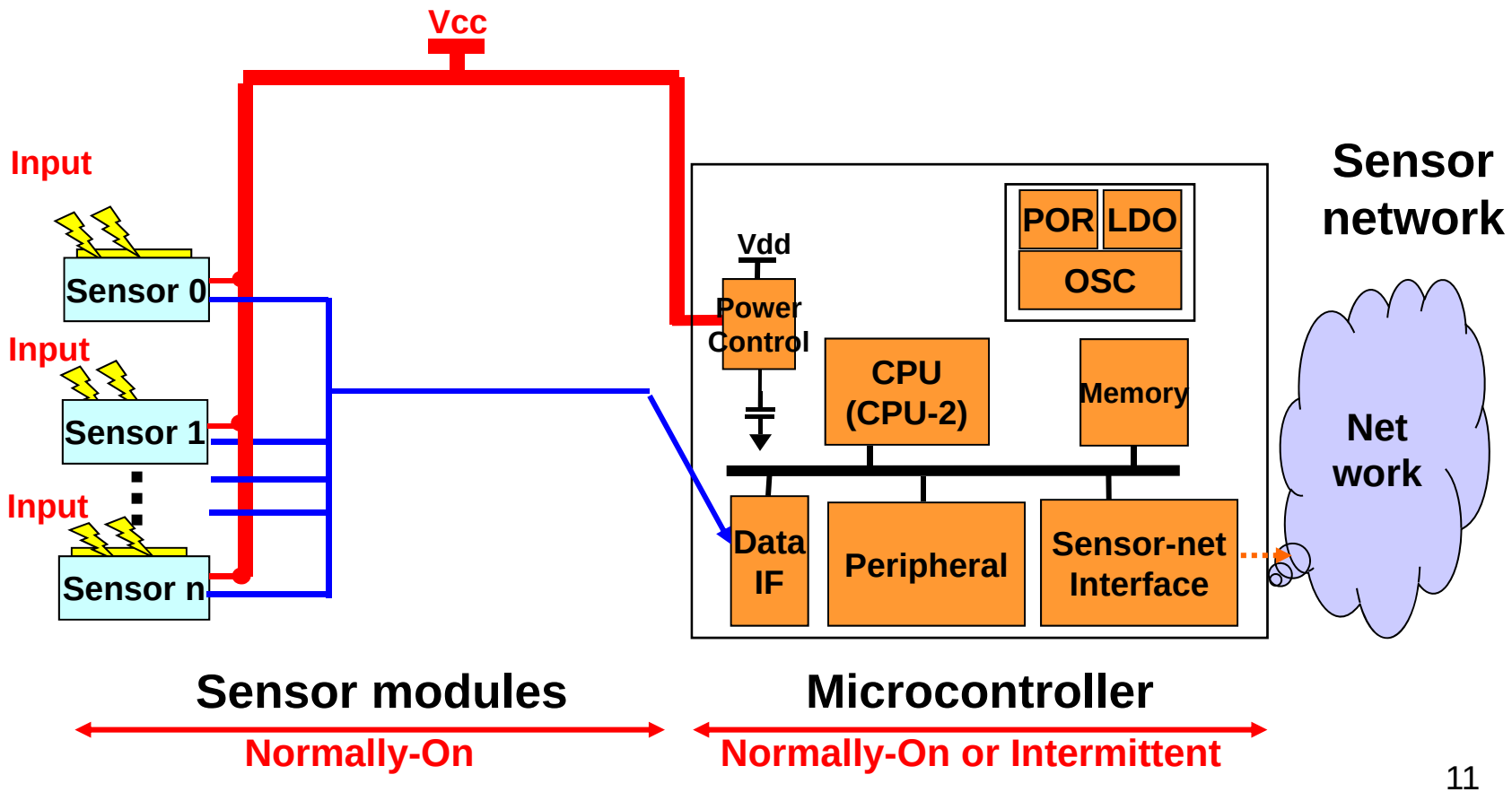
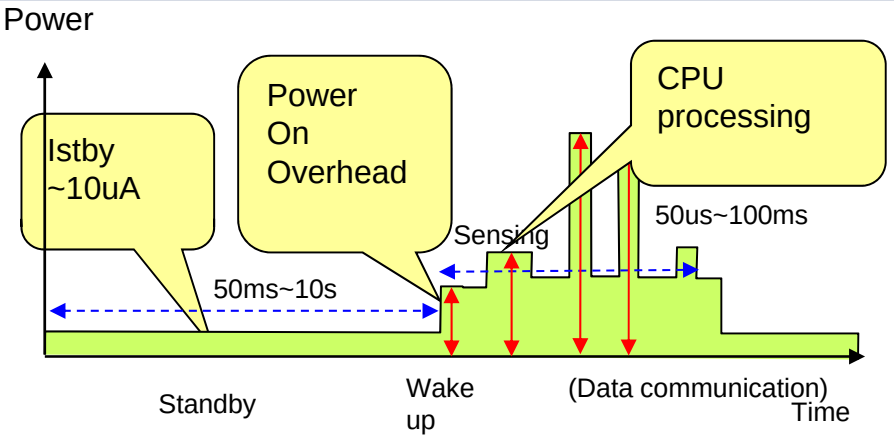
Conventional Sensor node

- Sensor-modules are in “Normally-On”.
- Microcontroller is in “Normally-On” or “Intermittent”.

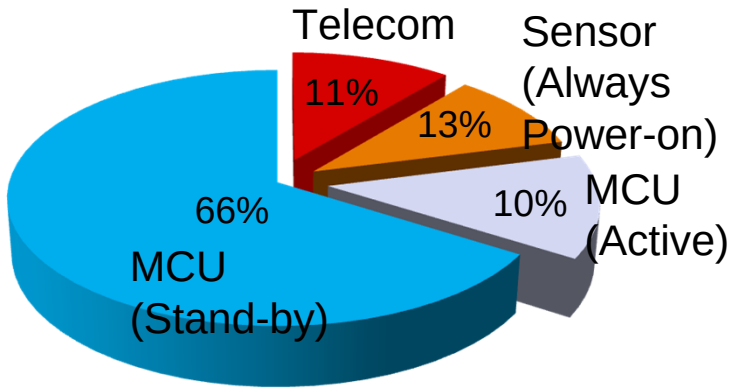


Challenge for Low-power Sensor nodes

Power consumption change of sensor nodes



Breakdown of power consumption of sensor system



Challenge for low-power consumption

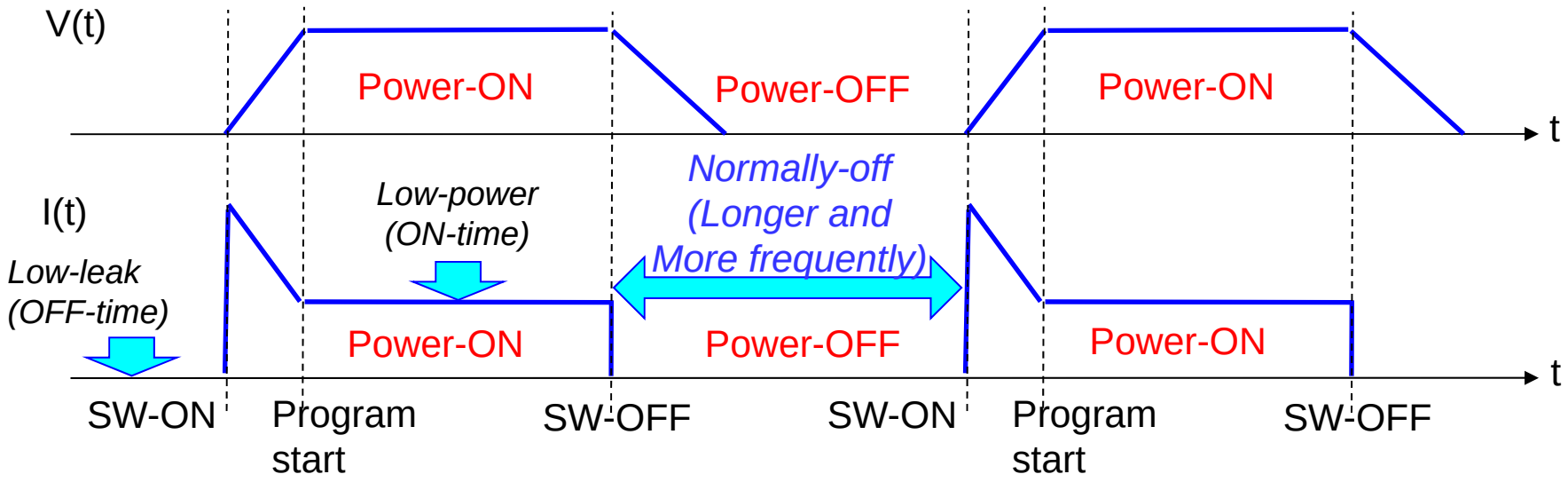
- Maximize power-off period. (MCU and Sensor is power on, when necessary)
- Reduce the active current.

Power On/Off Overhead

- Power On and Off has Power and Time overhead.
- “Normally-off Computing” should manage the overhead to reduce total-power .

➡ Maximize Power-Off period
- Longer Off-time, and More frequently

Minimize Power-on energy
- Lower active current, and Shorter On-time



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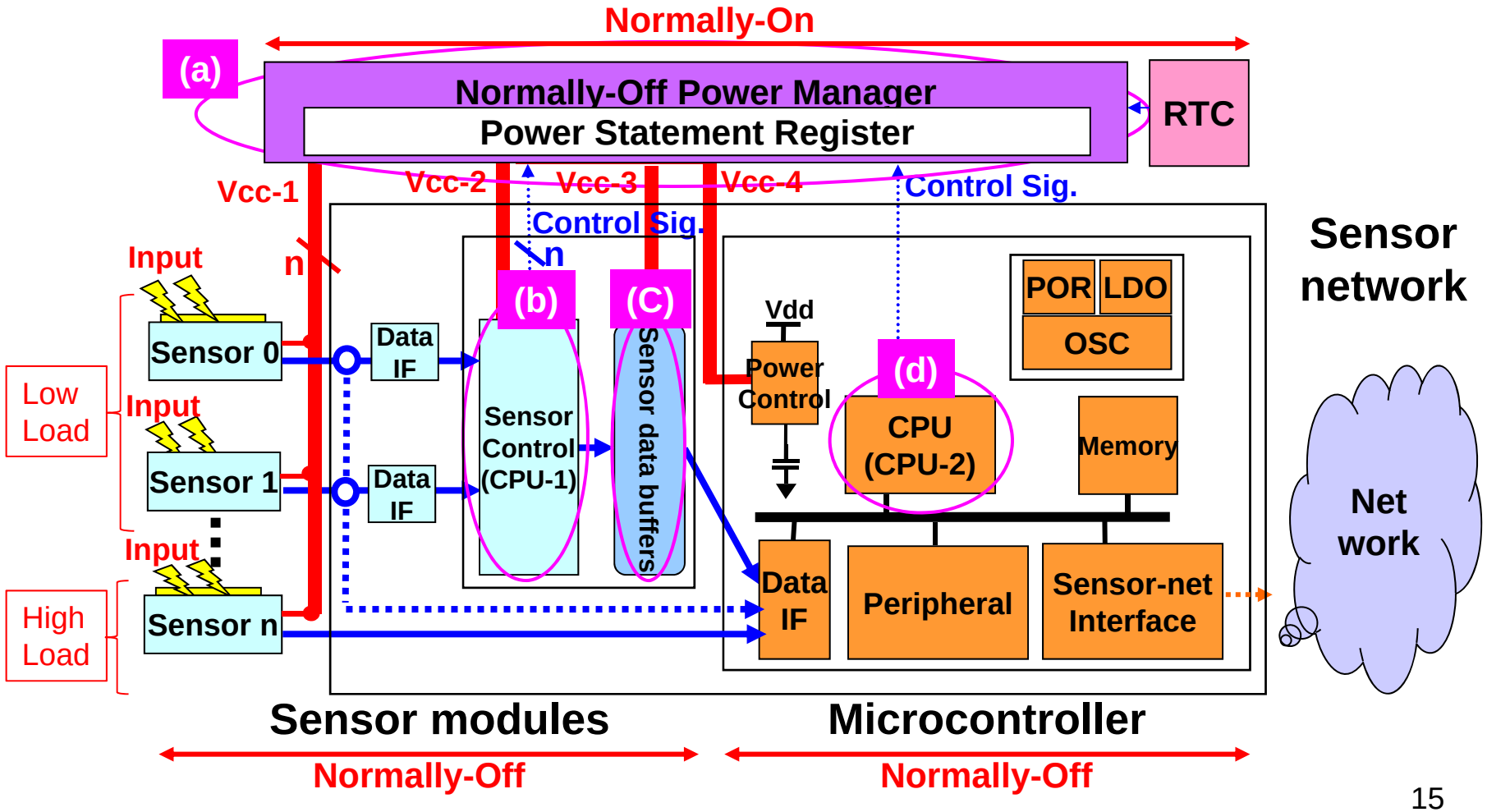
Normally-Off Architecture for Low-power Sensor node

- Sensor-modules are in “Normally-Off”.
- Microcontroller is in “Normally-Off”.



Normally-Off Architecture for Low-power Sensor node (Continue)

- Challenge is how to control the following key components.
  - Normally-Off Power Manager (a)
    - “Power Manager” controls power on/off in all units with data of “Power Statement Register”, and
    - Manages task-level scheduling for activity localization.
  - Sensor Controller (b)
    - Simple processing (e.g. data sampling) which was carried out in the microcontroller, are performed in “Sensor Controller”.
  - Sensor Data Buffer (c)
    - Sensor data are stored in “Sensor Data Buffer”. After that, microcontroller performs the processing at once to reduce the number of power-on of microcontroller.

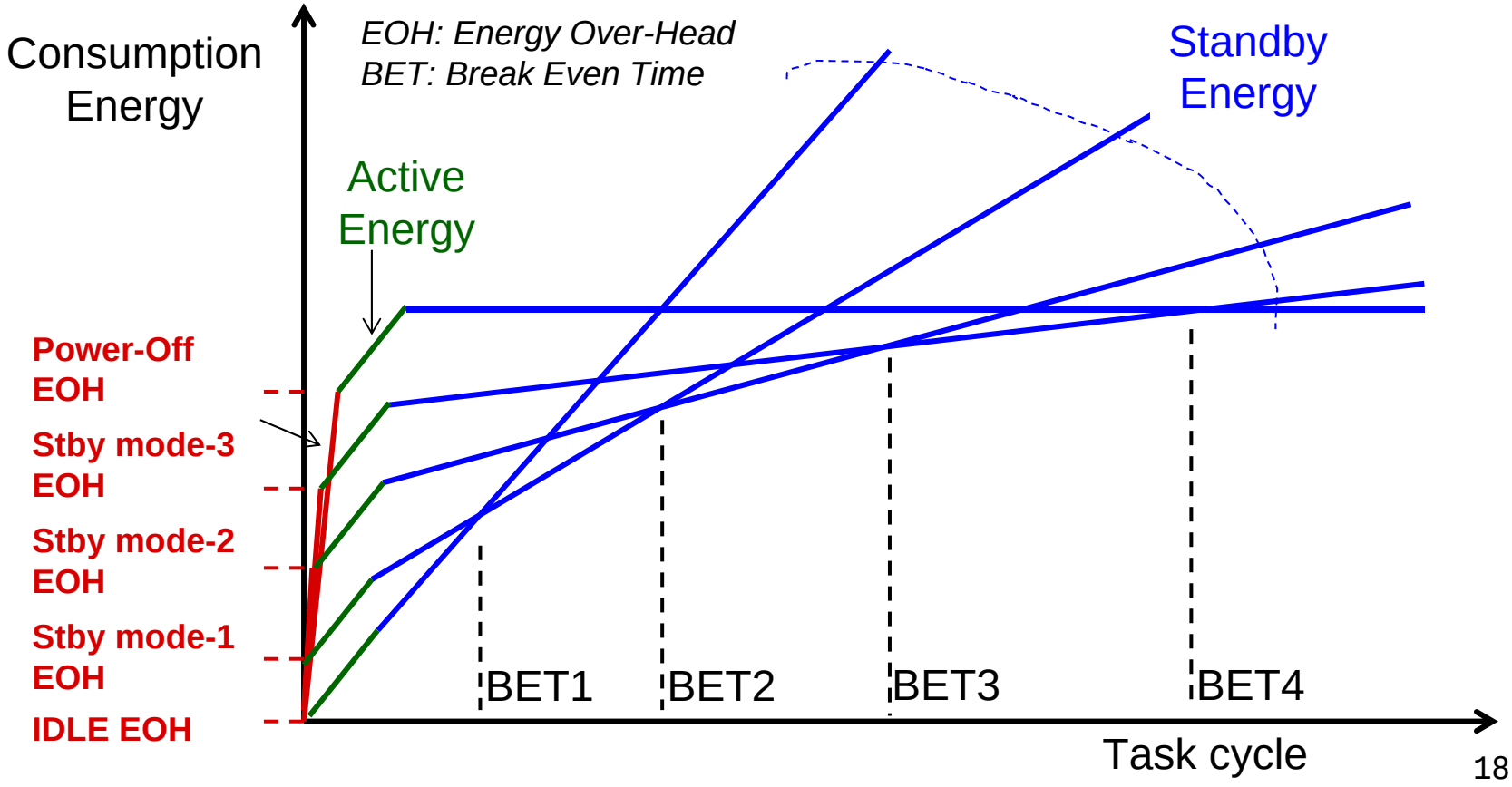
Normally-Off Architecture for Low-power Sensor node (Continue)

- CPU in Microcontroller (d)
  - Proposed architecture is consists of heterogeneous CPUs with Sensor Controller(b) and CPU(d).
  - Sensor required high load task, such as a Image sensor, is directly processed at CPU(d).
  - Task processed at Sensor Controller(b) and CPU(d) respectively should be optimized with task-level scheduling method.

➡ Thus, it is possible to reduce the operating frequency of the microcontroller, and to maximize the power-off time of microcontroller.

Normally-Off Power Management (1)
Autonomous standby mode transition

- Current microcontroller has some standby modes.
- "Normally-Off Power Manager" also supports the "Autonomous standby mode transition technology" to select optimal standby mode for programmer's usability improvement.

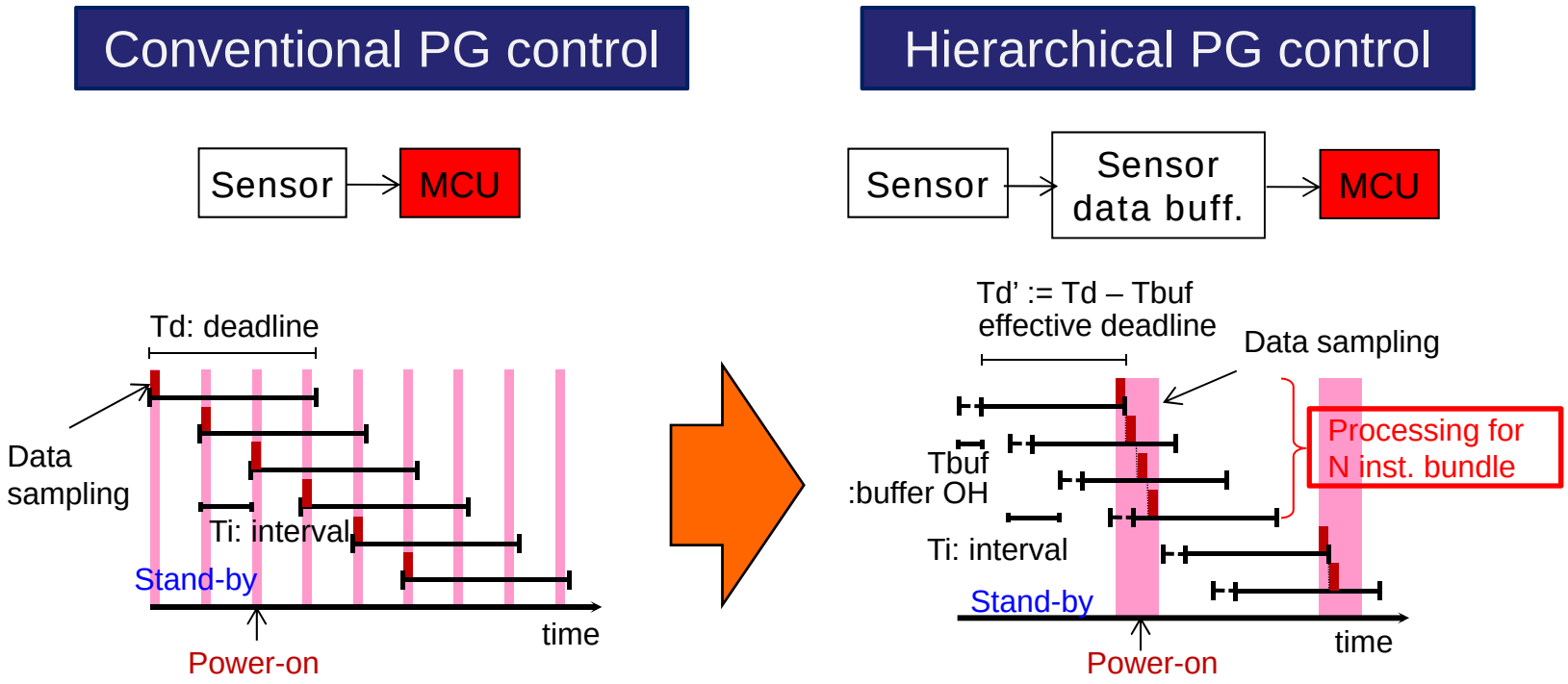


Normally-Off Power Management (2)

Activity Localization technology

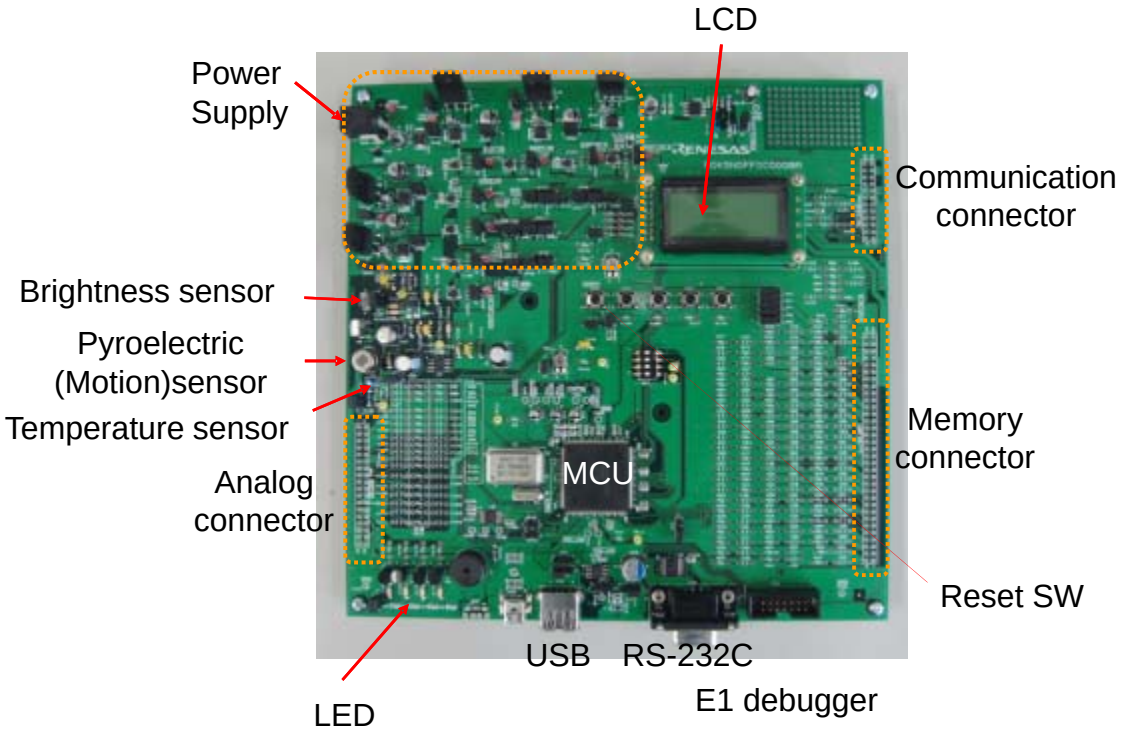
- Sensing data is buffered in sensor data buffer, and after then, microcontroller is activated and performed the process at once.

➡ It is possible to optimize the number of power on/off cycles and decrease power consumption energy.



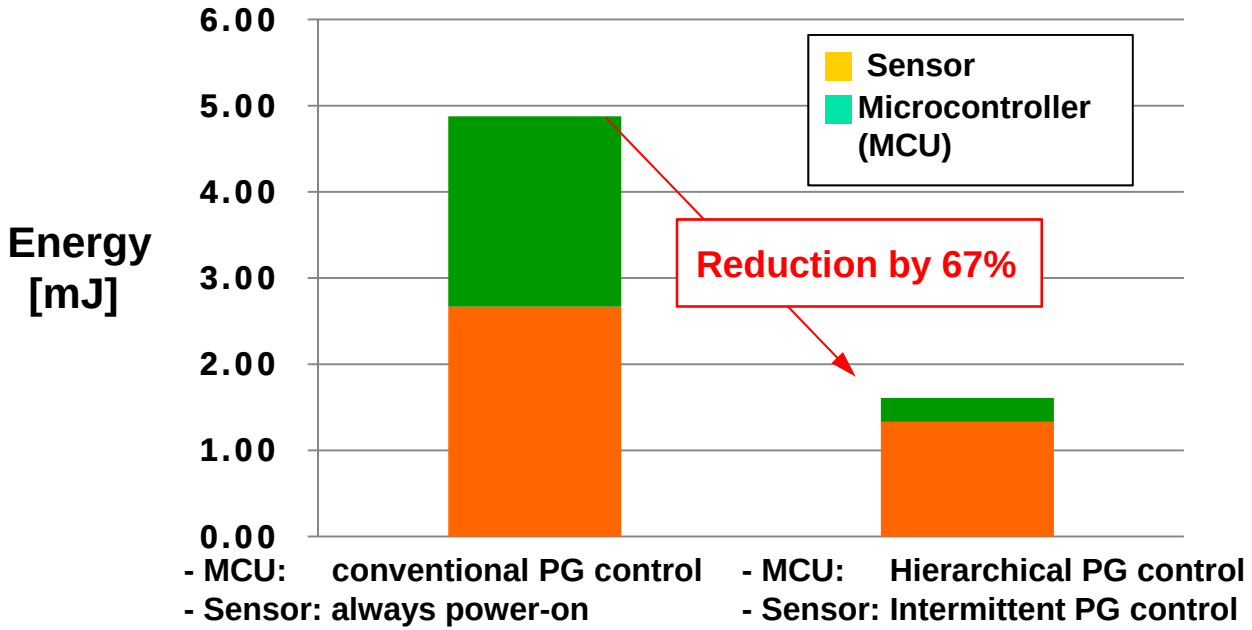
Evaluation Board

- Evaluation board is consist of,
  - Sensor (Temperature, Brightness, Pyroelectric(Motion))
  - Microcontroller
  - Other Peripheral circuits



Evaluation Results

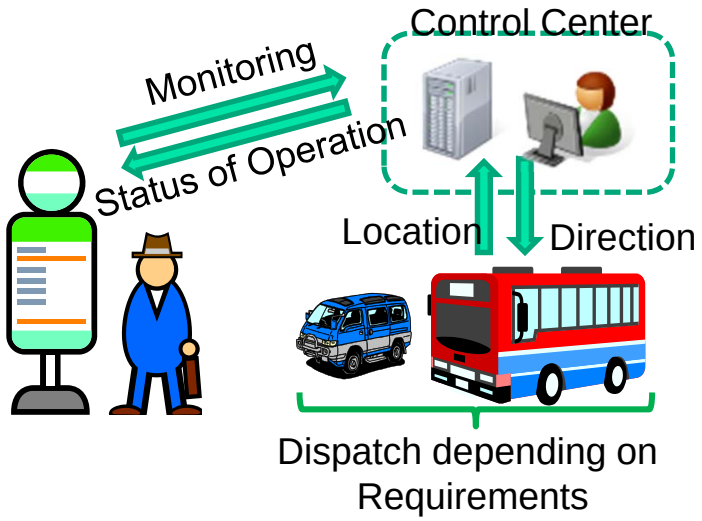
- Power consumption energy is reduced by 67%.



[Condition]
- 3 sensors (Temp., Brightness, Pyroelectric)
- Sampling cycle = 1s
- Processing period = 4ms
- Room temp.

Demonstration of Normally-Off Microcontroller system

- Demonstrate effectiveness and adaptability of normally-off microcontroller system.
- Demand transportation system with Normally-Off sensors (Pyroelectric, Camera) are under development as a demonstration with Future University Hakodate.



Demand transportation system based on Intelligent bus stop

Intelligent Bus Stop System with Normally-Off.

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Summary and Conclusion

- Production volume of sensor nodes is much increased with the development of cyber-physical systems.
- Normally-off architecture of microcontroller for future low-power sensor node has been proposed to reduce the power consumption of huge sensor nodes.
- To realize true low-power effects with normally-off computing technology, a co-design of hardware and software technology is very important.
- In this work, the power consumption energy is reduced by 67%.
- Normally-Off Computing is a candidate for future low power sensor networks.

Thank you for your attention.