

# **Efficient-Communications for Data-Intensive Applications**

**Nga Dinh, Ph.D.**

April 25, 2019

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- Applications
- Energy-Efficient Communications
- Bandwidth-Efficient Communications
- Conclusion

# Applications

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## The Distributed Arctic Observatory (DAO) project in a few words

Nowadays, to do ground-based in-situ observations of hard to reach places on earth, researchers carry wild life sensors, cameras and other observation devices into the field, manually configure the devices while on the abroad places. They then fetch the collected data several months later, by hand.

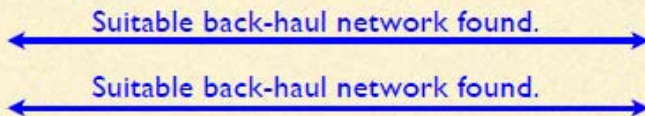
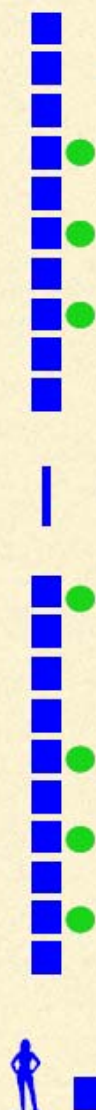
This approach does not scale. Deployment, configuration, observations, reporting of devices and data must be automated.

The Distributed Arctic Observatory (DAO) project proposes a hardware and software solution to these problematics. A DAO observation unit (OU) is a configurable computer node along with a set of sensors. These units will autonomously monitor themselves and the environment, run software layers able to configure and run new applications, synchronize data and finally gather data to centralized servers to execute analysis processes.

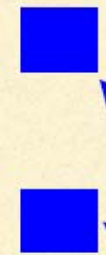
<https://site.uit.no/dao/>

**In-situ Autonomous Obs. Units**  
(Computer,  $\mu$ -controller, sensors, battery)

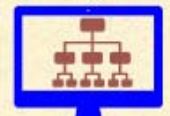
**DAO State of the Art**  
("Observe by Wire")



**Backend Observation Units**  
(With more resources)

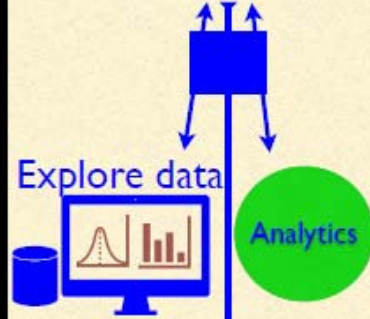


Status & Control



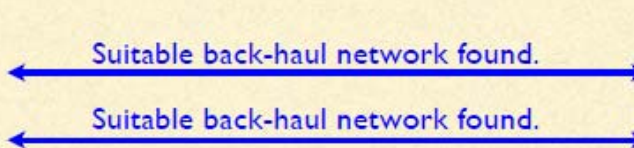
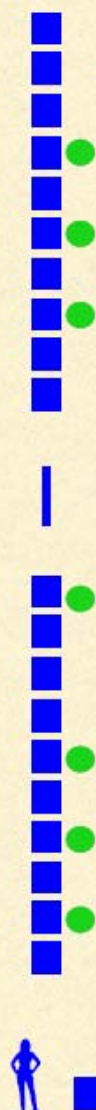
**Research Challenges**

- On-demand **Energy**
- On-demand **Connectivity**
- Data abstraction** e2e (consistency, durable)
- On-demand **Configuration**
- On-demand **Keep-alive**
- On-demand **Heating**
- On-demand **Deployment** (units, bait)
- On-demand **Inspection & Monitoring**
- (On-demand **Resistance** to malware)
- Optimisations** (system+auton. OUs)
- Analytics**
- The Artifact** (*scalable, energy, CAP*)

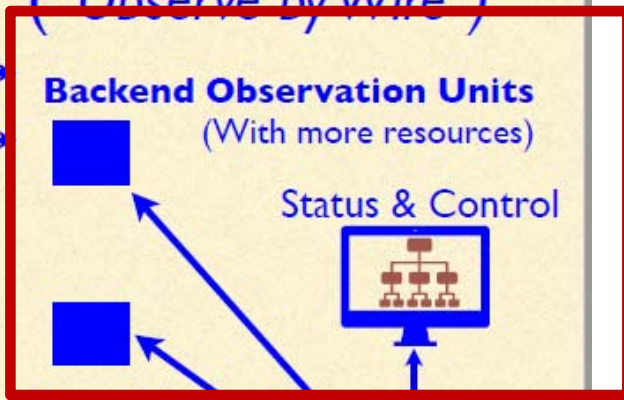


5 : 10 **commodity** prototype, to be **deployed**  
5 : 5000 **non-commodity** ASICs

**In-situ Autonomous Obs. Units**  
(Computer,  $\mu$ -controller, sensors, battery)

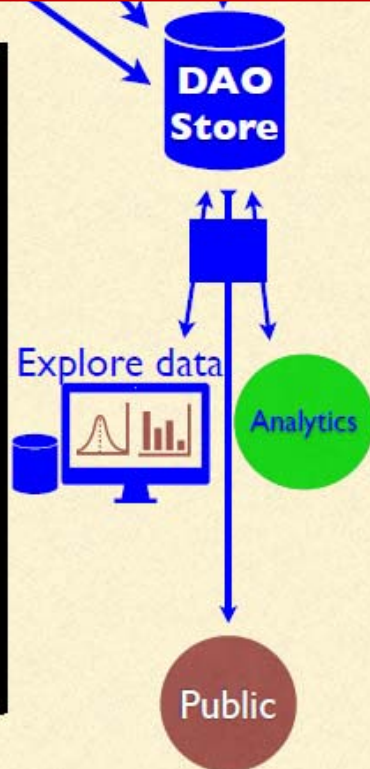


**DAO State of the Art**  
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**Research Challenges**

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5 : 5000 **non-commodity** ASICs

# Cyber Physical Systems



Cyber



Physical



CPS

# CPS Applications



**Agriculture**



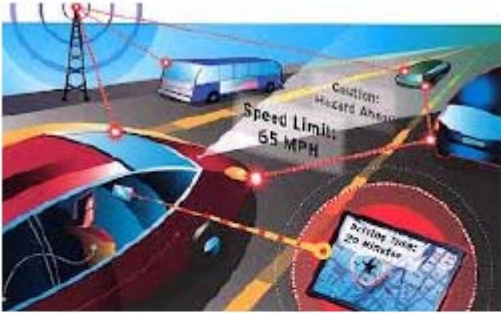
**Defense**



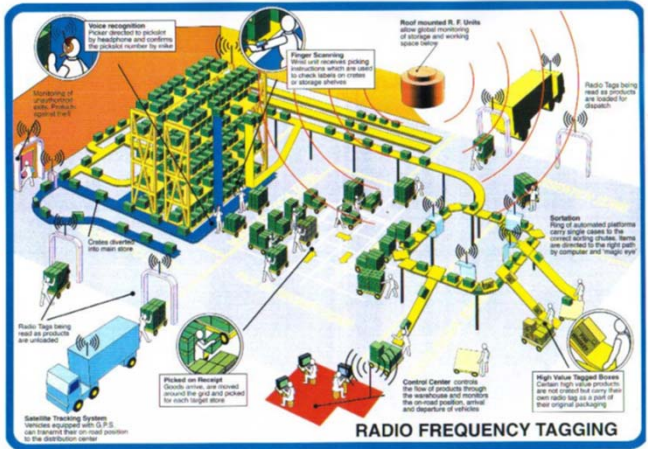
**Energy and Industrial Automation**



**Healthcare and Biomedical**



**Transportation**



**Critical Infrastructure**

# CPS Applications



**Agriculture**



**Defense**



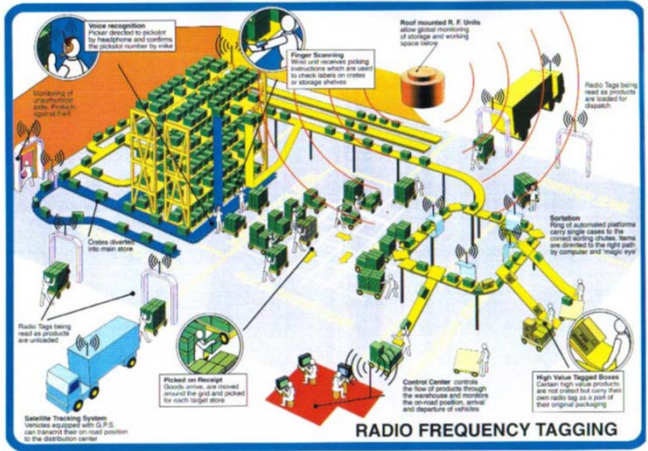
**Energy and Industrial Automation**



**Healthcare and Biomedical**



**Transportation**

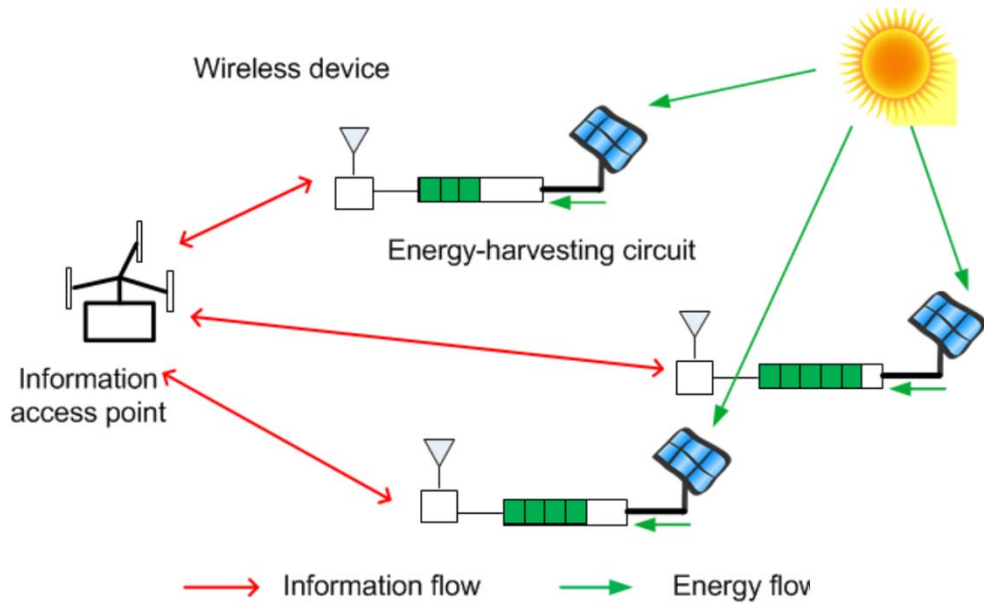


**Critical Infrastructure**

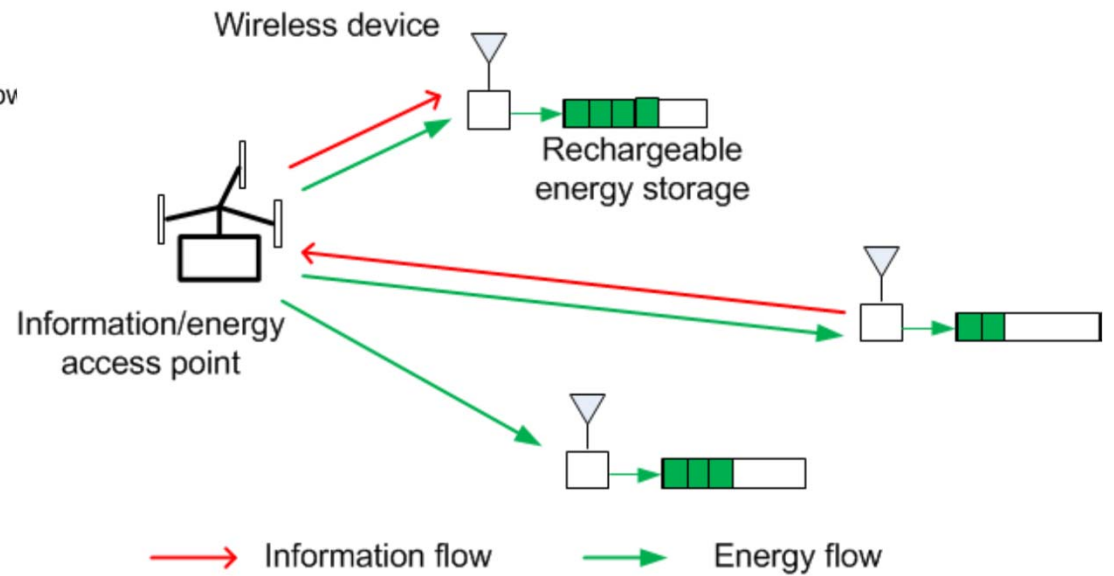
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# Energy Harvesting



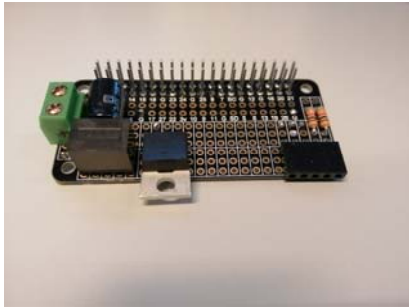
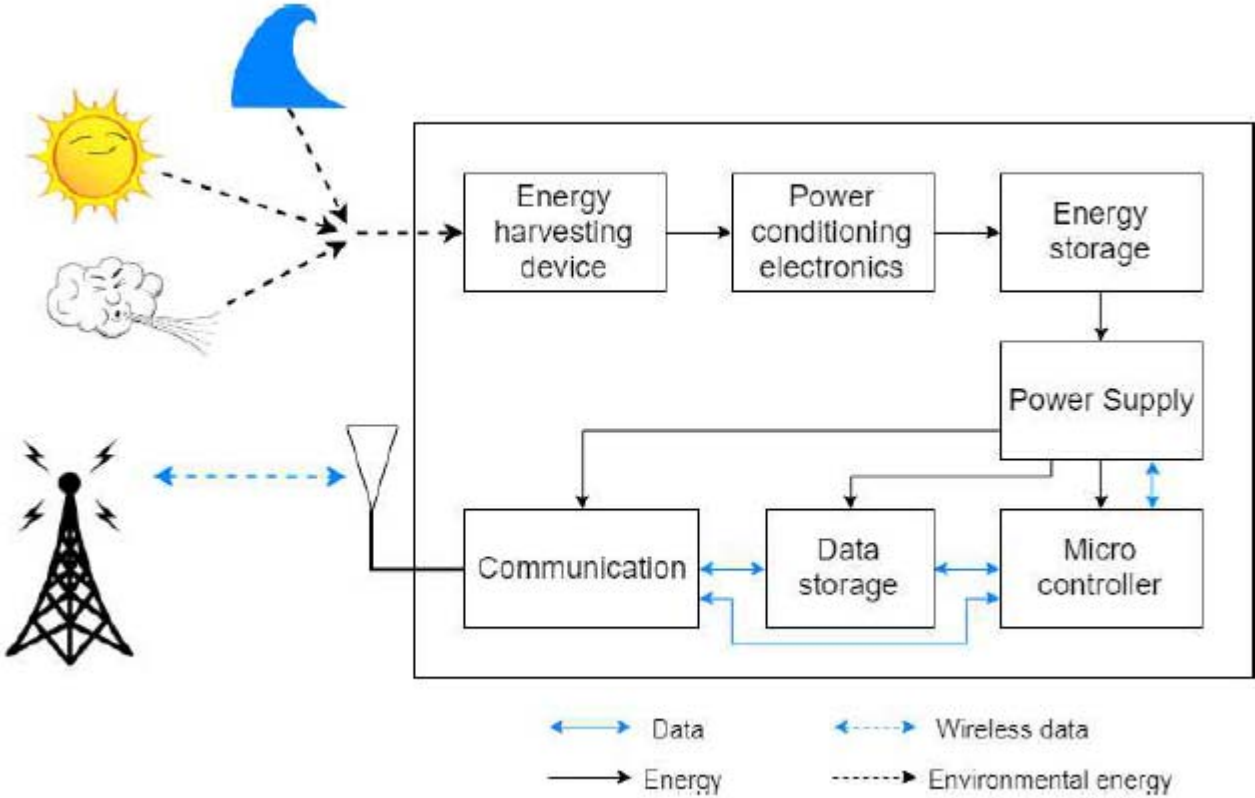
## Renewable Energy



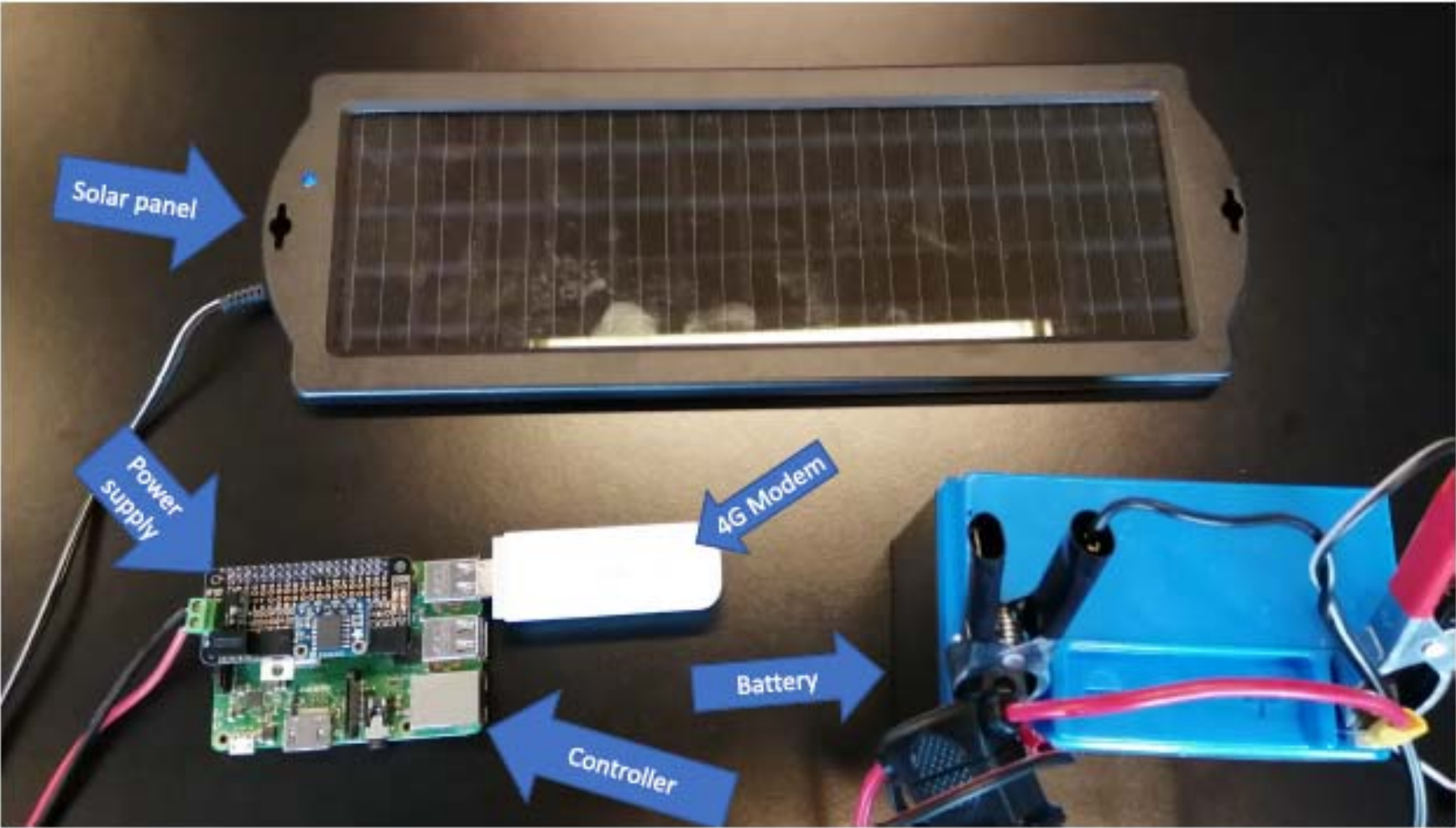
## Wireless Power Transfer

• Source: Rui Zhang, ICC Keynotes, 2015.

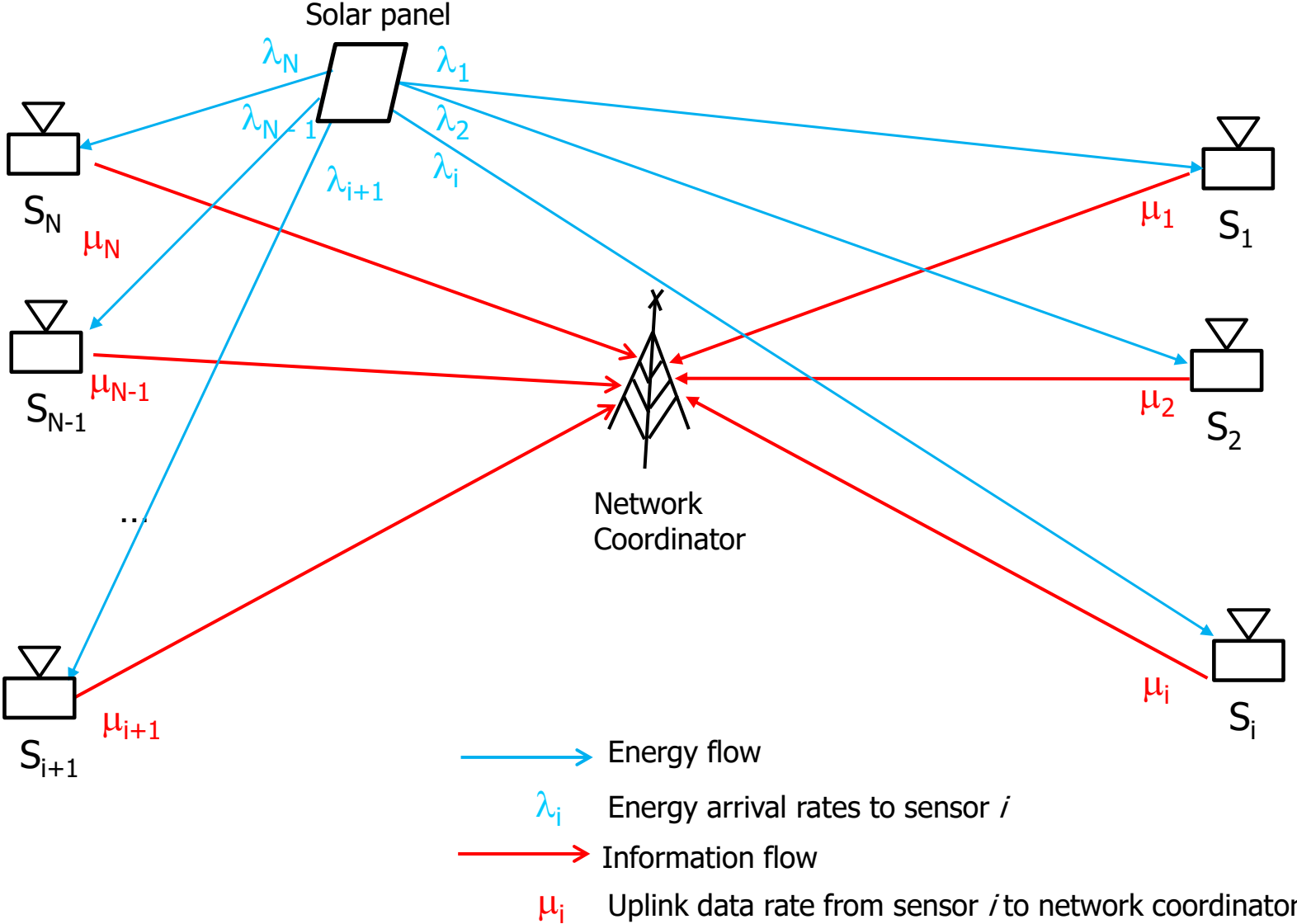
# Renewable Energy – Propose an EH method



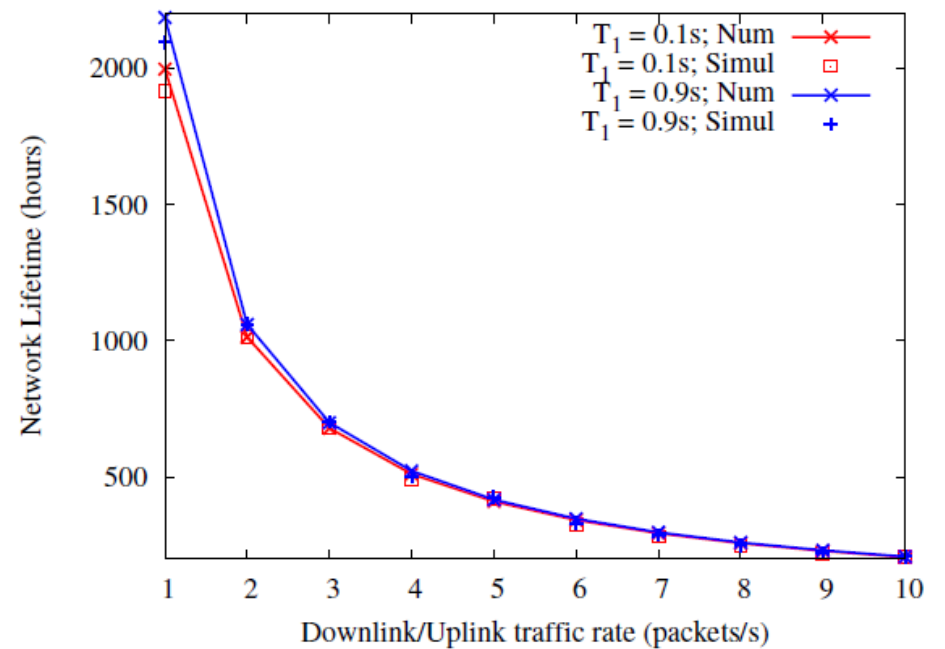
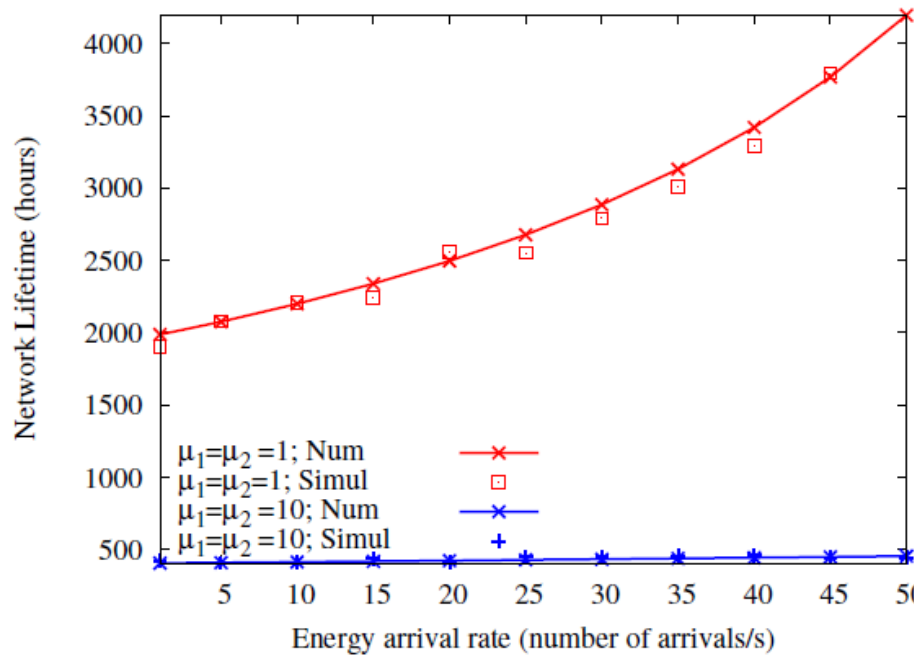
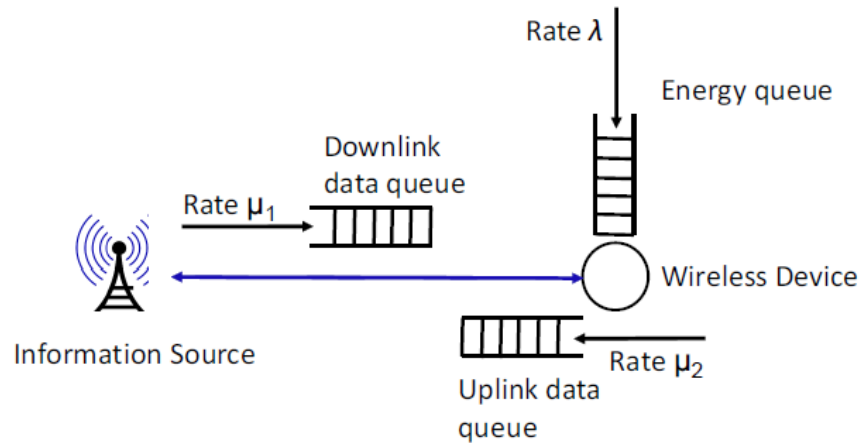
# Renewable Energy – Propose an EH method



# Renewable Energy – Evaluate the performance of EH systems

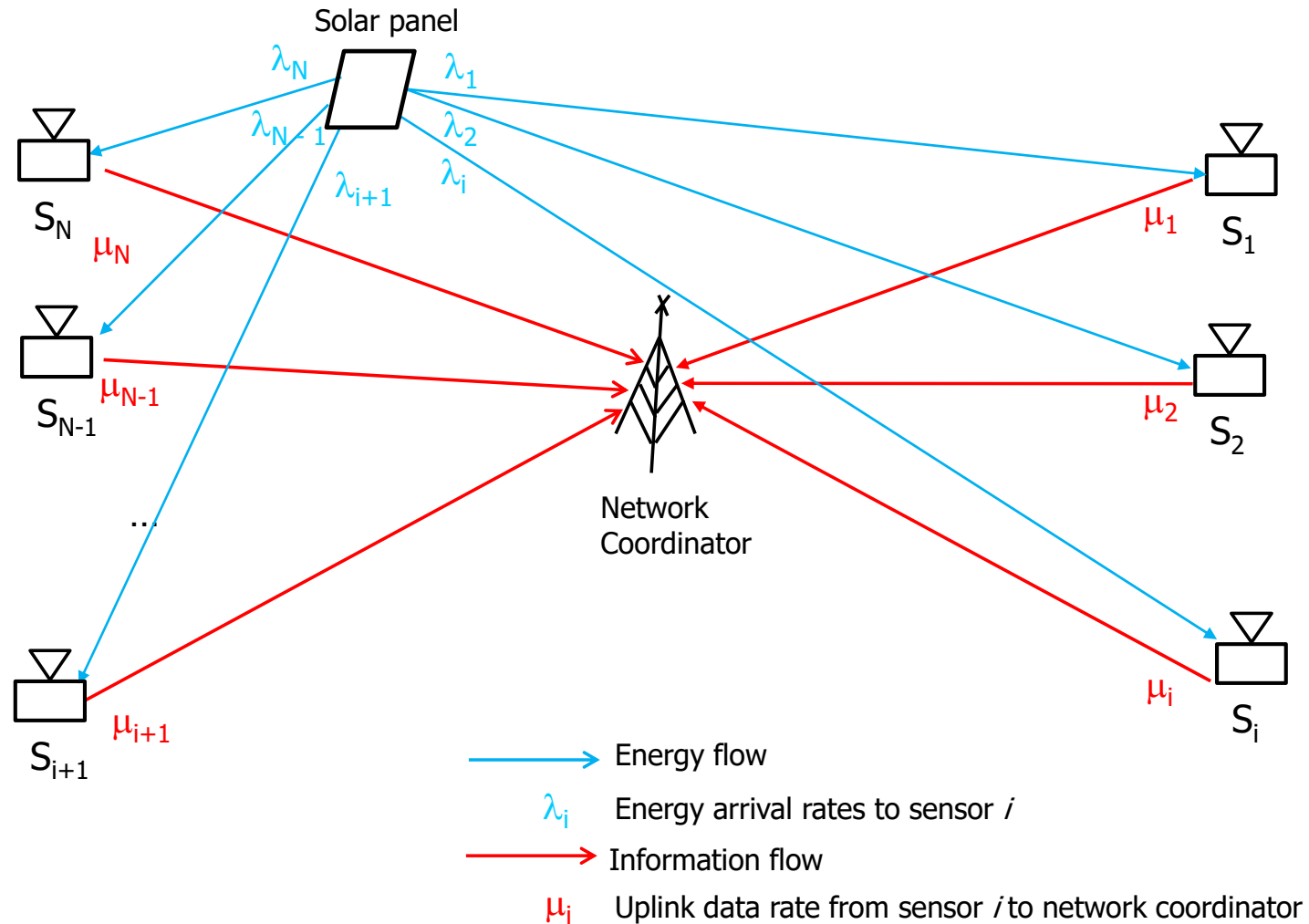


# Renewable Energy – Evaluate the performance of EH-based WSN



# Renewable Energy – Optimal policies for network performance

- Task scheduling among sensors in the network to maximize network lifetimes



# Works on Wireless Power Transfer

- “Cooperative Energy Harvesting Solutions for Wireless Technologies”
- Patent filed

Application no: 20190218  
Applicant: Norinova Technology Transfer AS

## **Notification for the attention of the inventor**

Considering your interests as an inventor the Norwegian Industrial Property Office will hereby notify you of being indicated as inventor for the following patent application.

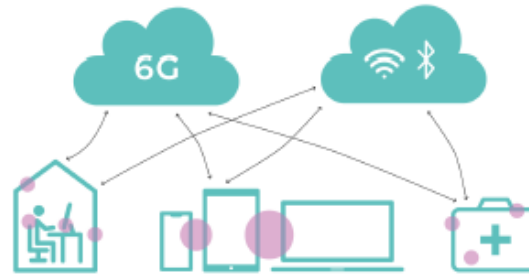
Details concerning the application:

Application no: 20190218  
Applicant: Norinova Technology Transfer AS  
Application date: 2019.02.18

The following inventor(s) is(are) listed:

Thi Thuy Nga Dinh, Duevegen 55, 9015 TROMSØ, Norge  
Phuong Hoai Ha, Tomasjordvegen 217 D, 9024 TOMASJORD, Norge

# Cooperative Power Transfer Approach in Wireless Technologies



## SUMMARY OF INVENTION

Researchers at Department of Computer Science at UiT - The Arctic University of Norway have several years working on energy efficiency in wireless technologies and energy harvesting (EH). The researchers are experienced in related hardware, software, and industrial productions. The proposed solution allows a wireless device to harvest energy from a dedicated energy source in current wireless technologies which were not designed for EH operation. In current commercial products, the integration of energy harvesting operation and information exchange in these technologies may result in backward compatibility problems with deployed products. Not being well-designed for energy harvesting may result in a reinvention of all wireless standards and this prohibits the use of energy harvesting networks in the real world. These problems are solved in our solutions.

## CURRENT STATUS

- Patent for cooperating and controlling energy harvesting operation in a wireless device in current wireless technologies available
- Software simulations available on request
- Demonstration of how devices work available

## WE ARE SEEKING

- Collaborating partners interested in applying our ideas on their commercial products
- Collaborating partners to implement ideas together
- Commercial partners for licensing of cooperating power transfer in current wireless technologies

### INSTITUTE

**UiT** / THE ARCTIC UNIVERSITY  
OF NORWAY

### INVENTORS

Thi Thuy Nga Dinh  
Hoai Phuong Ha  
Department of Computer Science

### BUSINESS DEVELOPMENT

Anne-Karin Måseide Olsen  
Morten Elde  
Norinnova Technology Transfer AS

### CONTACT

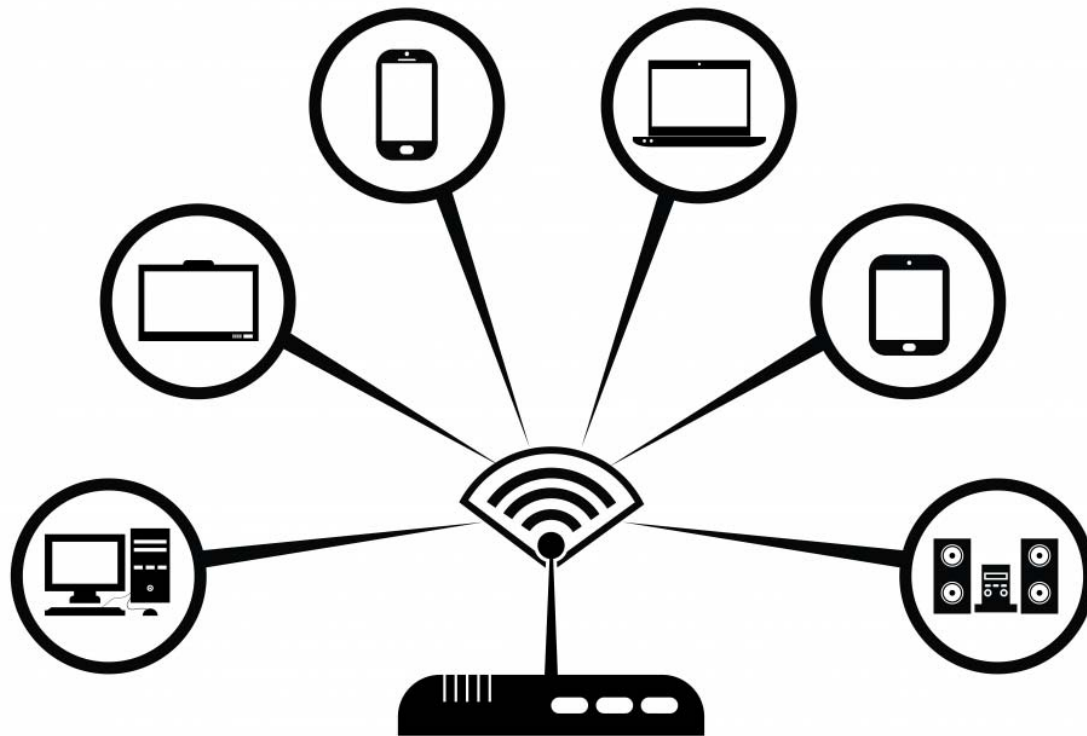
morten@norinnova.no  
Phone: +47 4140 6762

**norinnova**

Let's see a short video

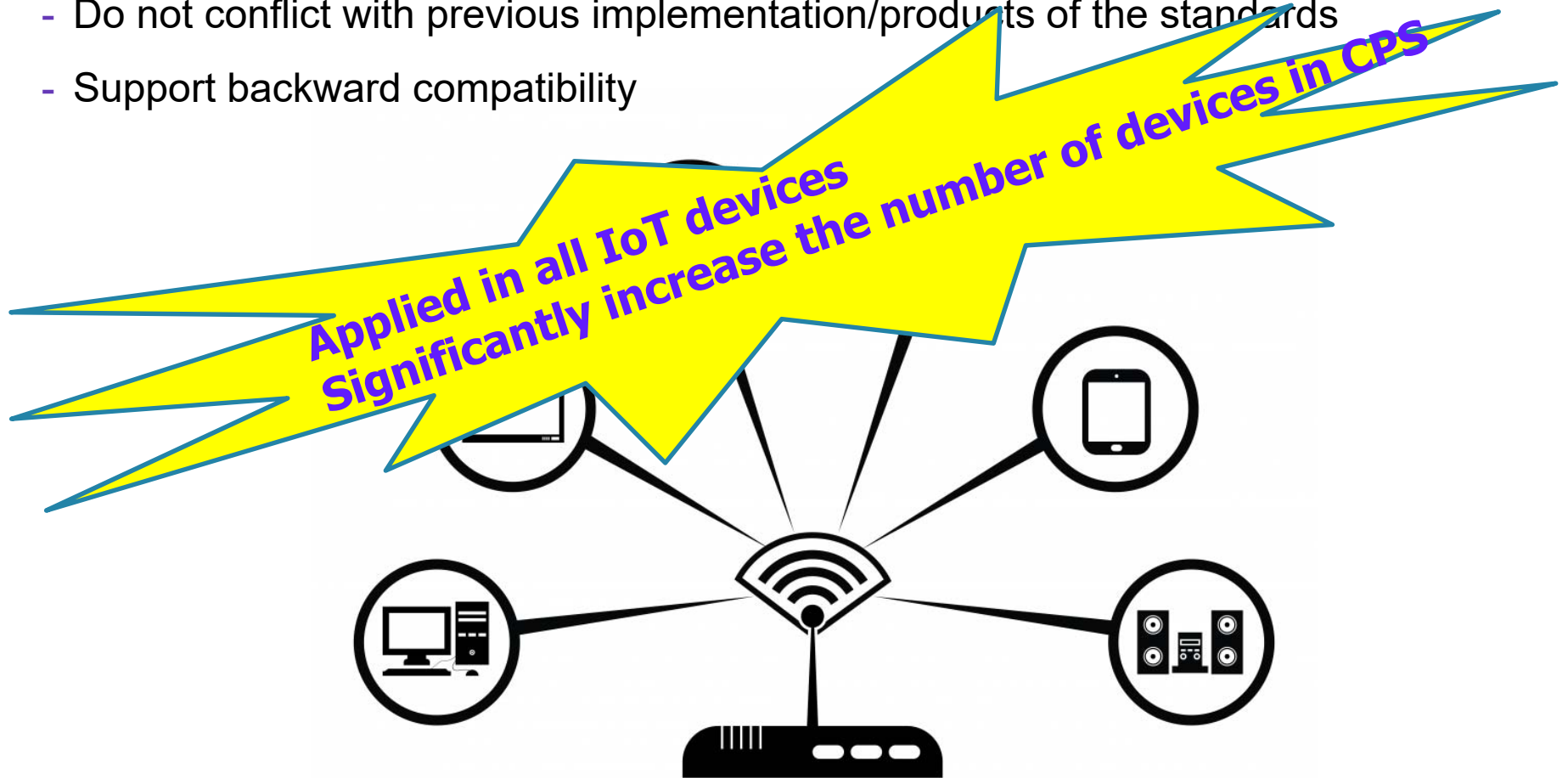
# Works on Wireless Power Transfer

- Proposed protocols and methodologies
  - Support power transfer in current wireless technologies: Wifi, Zigbee, LTE, 5G
  - Do not conflict with previous implementation/products of the standards
  - Support backward compatibility



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# Achievements



US 20170332375A1

- **Patents**

- US, KR

(19) **United States**  
(12) **Patent Application Publication** (10) **Pub. No.: US 2017/0332375 A1**  
**DINH et al.** (43) **Pub. Date: Nov. 16, 2017**

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(54) **DEVICES FOR A WIRELESS NETWORK SYSTEM AND COMMUNICATION METHODS THEREOF** **Publication Classification**

(51) **Int. Cl.**  
*H04W 72/04* (2009.01)  
*H04W 72/04* (2009.01)

(71) Applicant: **Samsung Electronics Co., Ltd.**, Gyeonggi-do (KR)

(52) **U.S. Cl.**  
CPC ... *H04W 72/0446* (2013.01); *H04W 72/0486* (2013.01)

(72) Inventors: **Nga Thi Thuy DINH**, Gyeonggi-do (KR); **Sangsoon LIM**, Seoul (KR)

(73) Assignee: **Samsung Electronics Co., Ltd.**

(21) Appl. No.: **15/439,566**

(57) **ABSTRACT**

(22) Filed: **Feb. 22, 2017** A data communication method of a hub device for a wireless

- **Papers:**

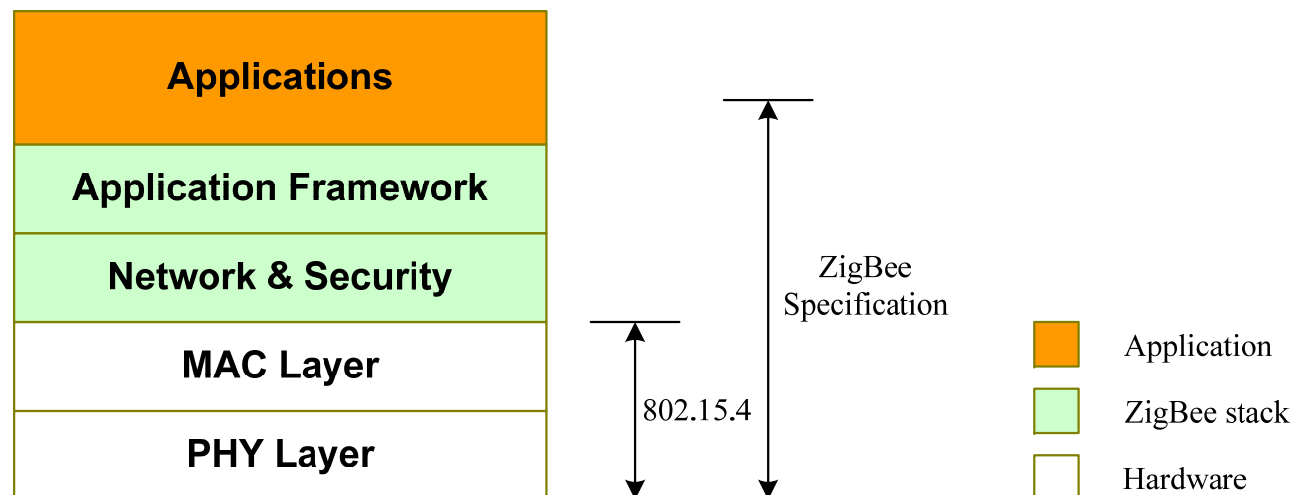
- **N.Dinh** and P. H. Ha, "Resource Management for Improving Performance of IEEE 802.15.4-Based Home Automated Systems", *Globecom 2018*.

- **Presentations:**

- "Resource Management for Smart Meter Using IEEE 802.15.4 Based Wireless Sensor Networks in Smart Grid", 2019 Arctic Frontiers Smart Arctic, Norway.

# Resource Allocation Optimization - 1

- Several wireless technologies can be used for CPS: WiFi, BT, Lora, BLE, Zigbee/**IEEE 802.15.4**
- IEEE 802.15.4 standard is widely used : easy to deploy, energy-efficient, low-cost
- Beacon-enabled IEEE 802.15.4:
  - Guaranteed Time Slot (GTS) can provide free access for delay-sensitive applications
  - Used for industry applications: smart homes, vehicular networks, monitoring, healthcare



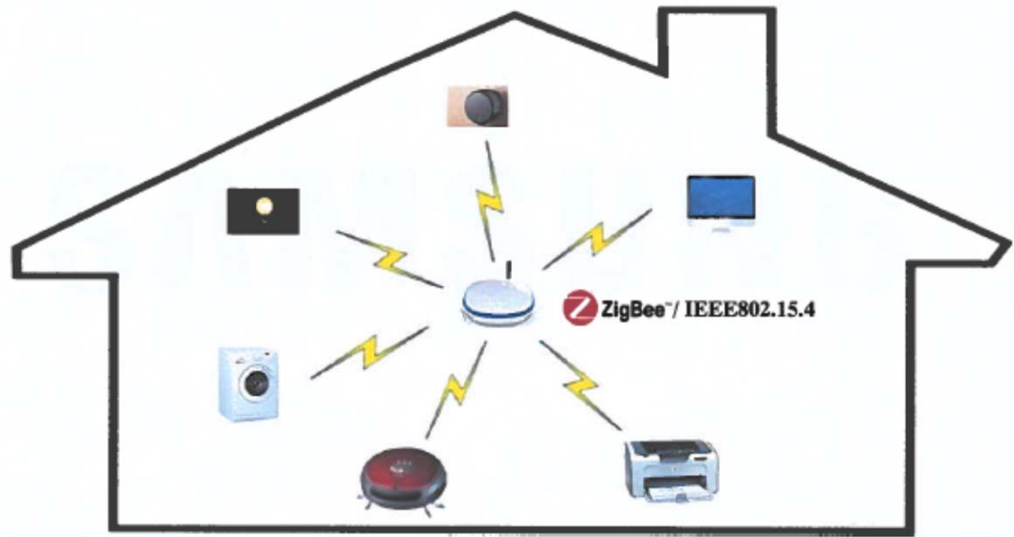
## Resource Allocation Optimization - 2

However:

- **Directly applying GTS scheduling in IEEE 802.15.4 is not efficient**
- The improvement of GTS scheduling requires adding more bits/fields to current standard or more layers to network stack
- **Backward compatibility problem** with deployed products
- In the IEEE 802.15.4 networks, coordinator fails to assess how much network bandwidth each sensor needs for its applications => **No optimization of network resource**

# Resource Allocation Optimization - 3

- 1. GTS Command Frame Modifications
- 2. Power Saving Algorithm



- 3. GTS Request Arrangement Algorithm
- 4. Resource Allocation Algorithm

# IEEE 802.15.4 Superframe structure

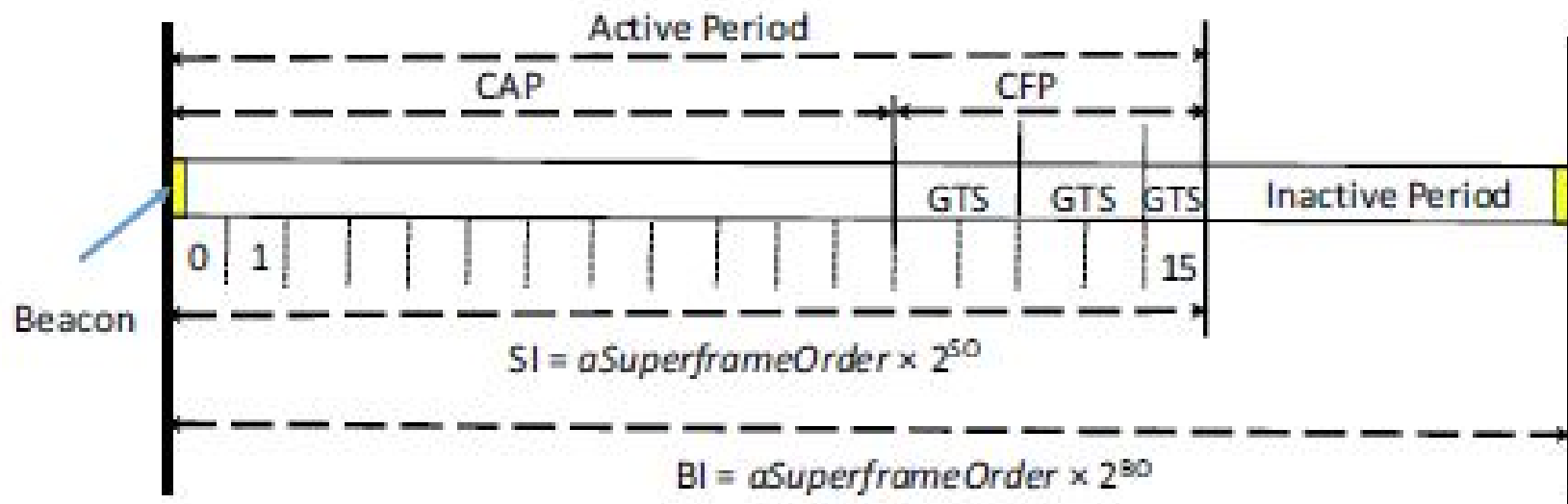
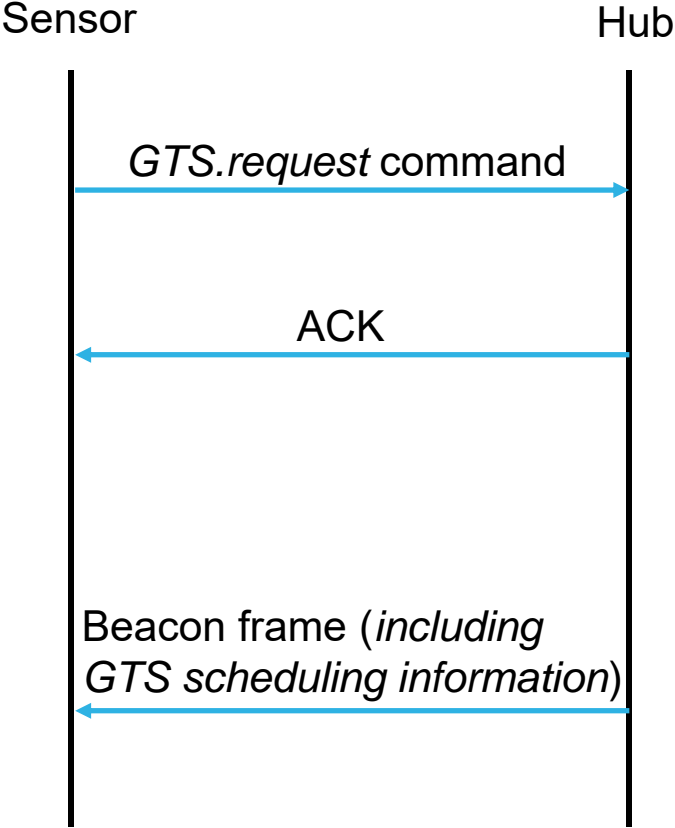


Figure 1. Superframe structure consisting of a CAP, a CFP, and inactive period.

# GTS Allocations in IEEE 802.15.4



*aGTSDescPersistenceTime* (4) superframes

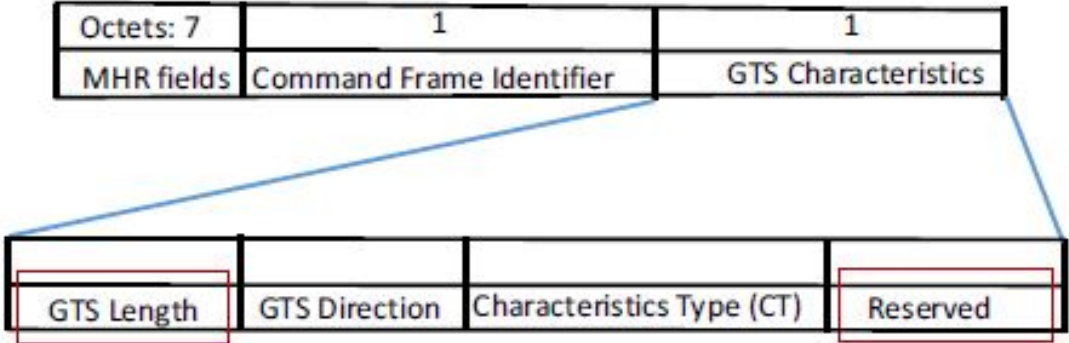
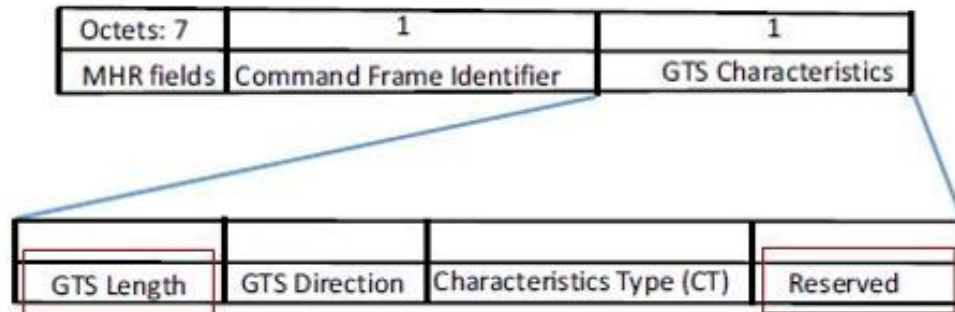


Figure 2. GTS command frame format.

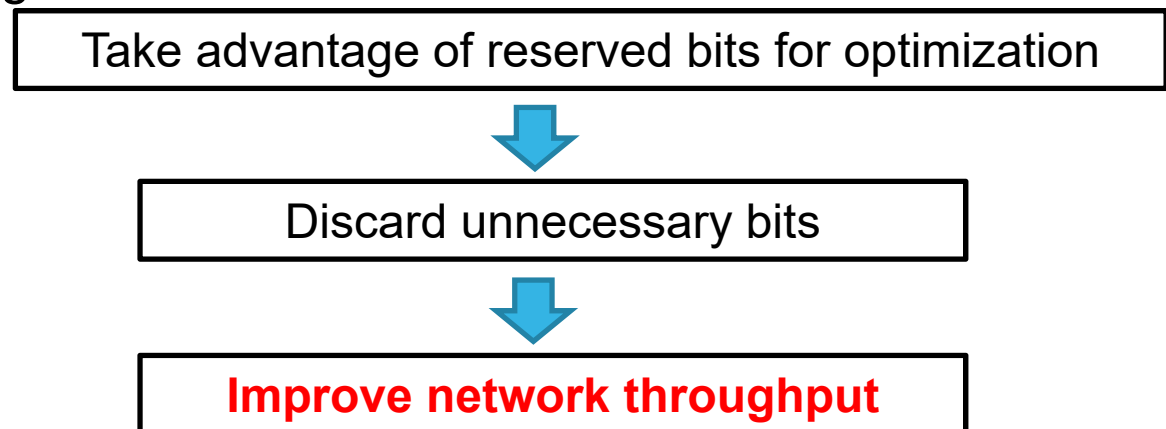
# GTS Command Frame Modifications

- Implemented at smart sensors
- In current technologies using IEEE 802.15.4 frame format, 'GTS length' field is used to indicate the number of GTS slots a sensor wants to use
- **'GTS length' and 'Reserved' fields are modified to indicate data length from sensors**



## Benefits:

- Provide data size information to the Hub => Hub can use this information for optimization purposes



# GTS Requests Arrangement Algorithm

- In the IEEE 802.15.4 standard, GTS requests are processed on a FIFO basis regardless of GTS allocation or deallocation
- **This approach is not optimal**
- The proposed algorithm is implemented at the Hub
- Hub maintains two separate queues: a *GTS allocation queue* and a *GTS deallocation queue* so that GTS releases can occur before the Hub services GTS allocation requests.

# Power Saving Algorithm

- Performed by a sensor which requests GTS to minimize its power consumption
- **Basic idea:** even in the active period of a superframe, sensor can turn its power off to further conserve power
- IEEE 802.15.4 and all existing works, the sensor can only turn its power off during the inactive period.

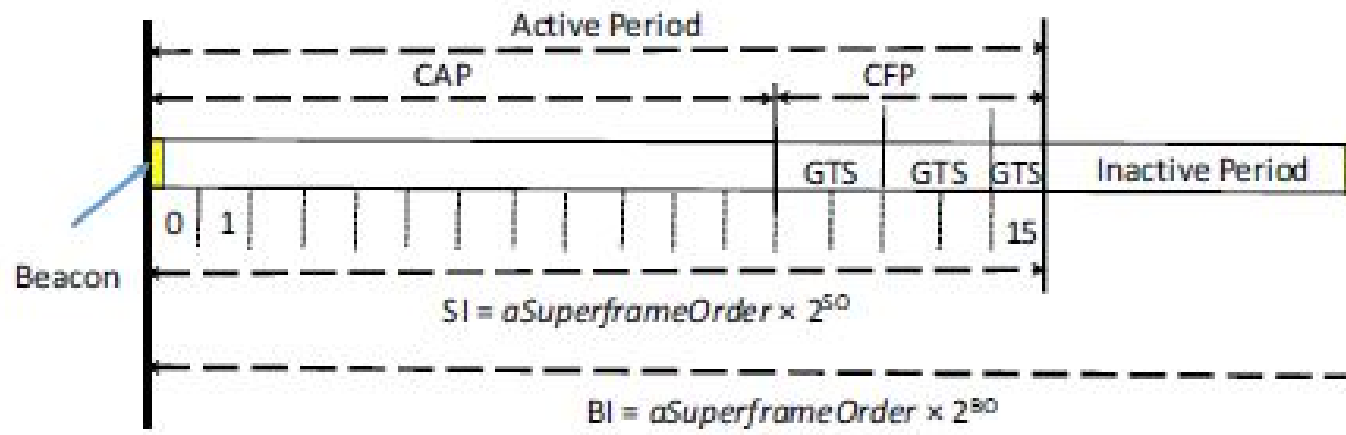
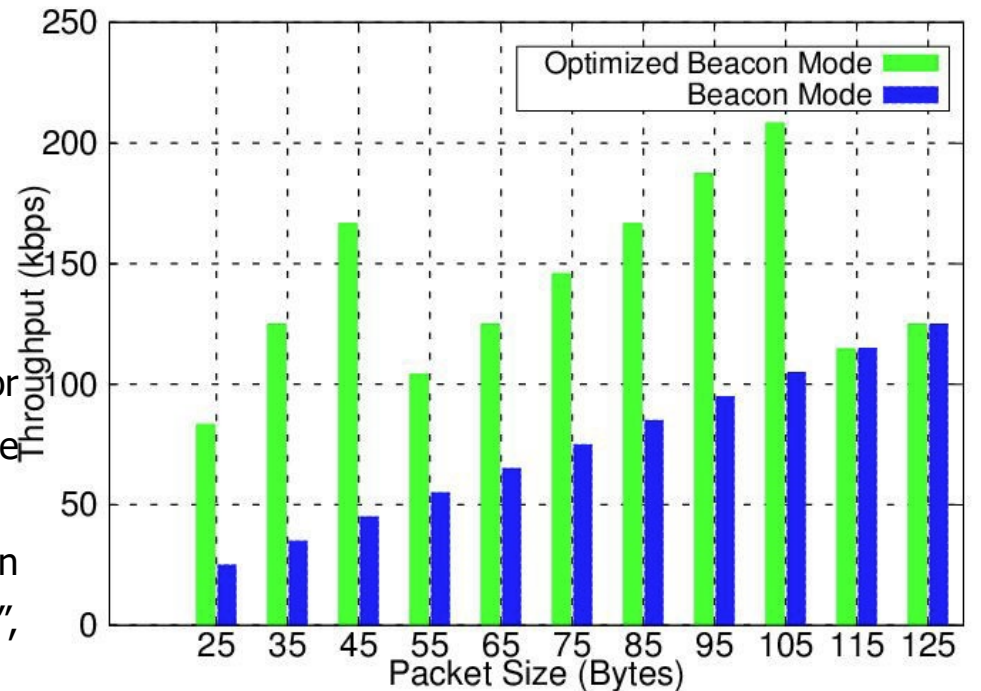
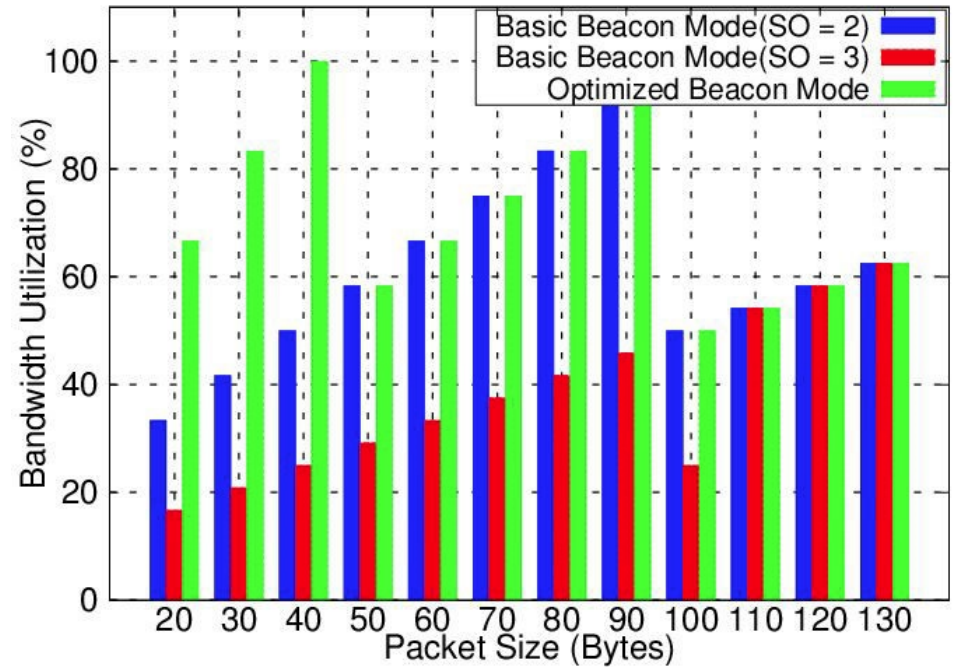
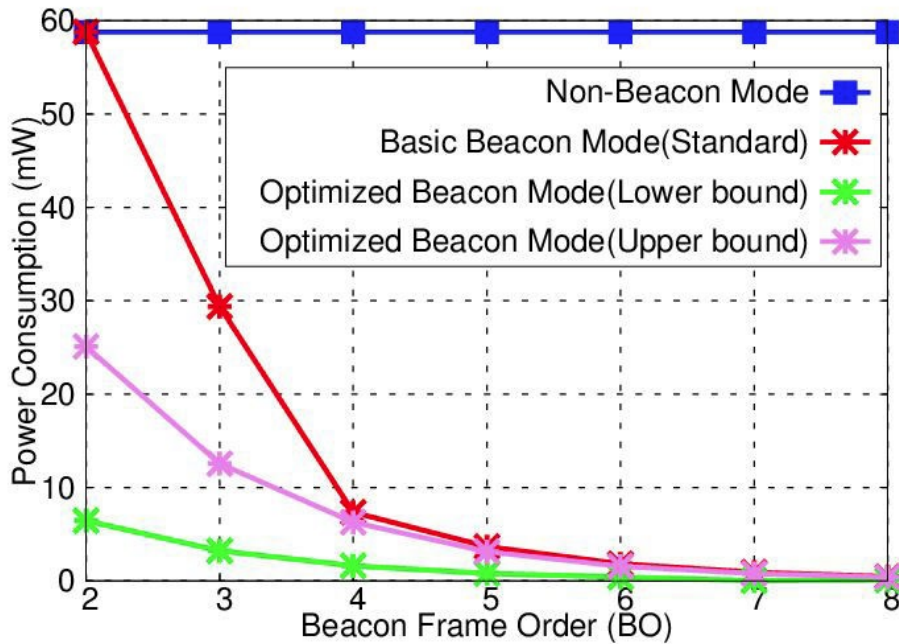


Figure 1. Superframe structure consisting of a CAP, a CFP, and inactive period.

# Performance Evaluations

- Star topology: 1 Hub and 7 sensors
- Sensors: periodically send 95-byte data frame to hub
- 2.4Ghz ISM band
- 5-byte ACK frame
- MAC header: 13 bytes, PHY header: 6 bytes, and beacon frame: 73 bytes
- Gap between sending data frame and ACK frame is negligible
- Currents consumption in CC2420 chip:
  - Transmitting state: 17.4mA, receiving state: 19.6mA, idle state: 0.396mA
  - Transition time from TX/RX to Idle state: 0.2ms with maximum power consumption

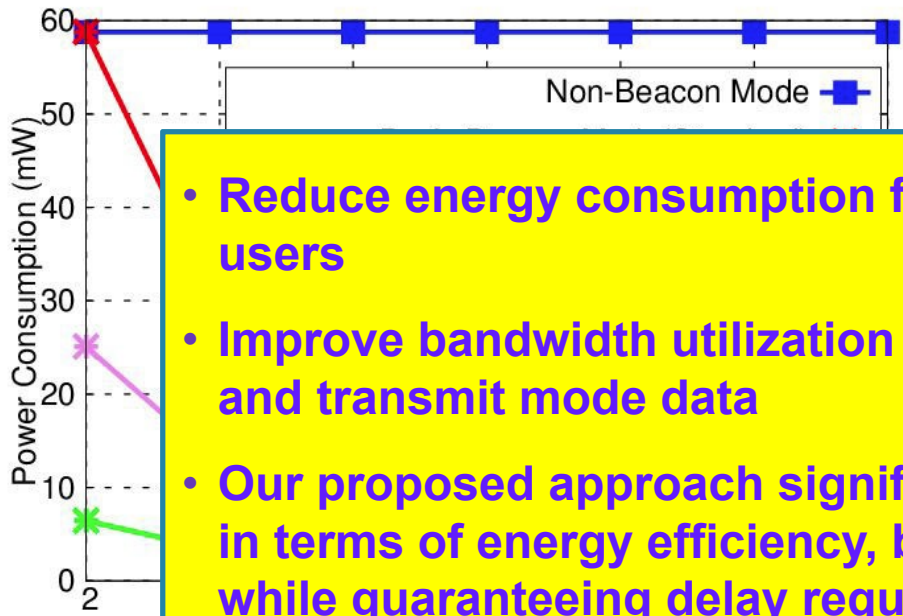
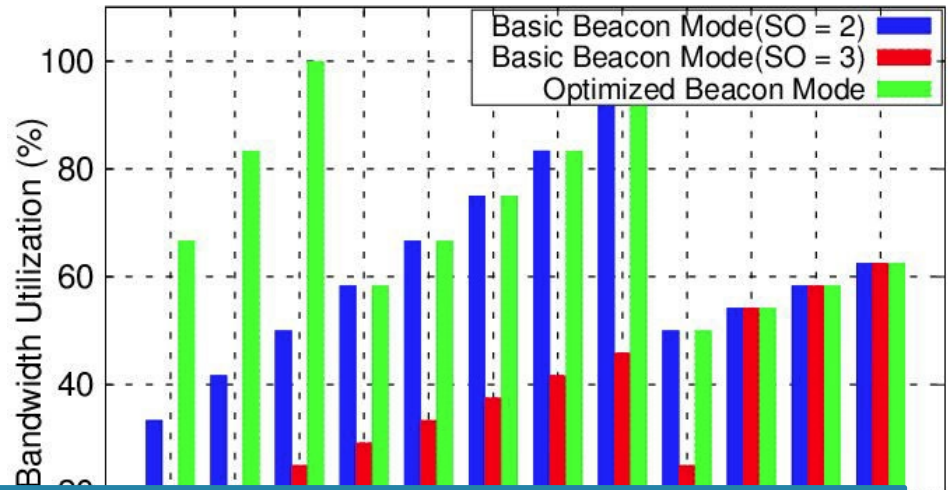
# Performance Evaluations



[1] **N.Dinh** and P. H. Ha, "Resource Management for Improving Performance of IEEE 802.15.4-Based Home Automated Systems", *Globecom 2018*.

[2] **N.Dinh** and P. H. Ha, "Advanced GTS Scheduling in IEEE 802.15.4 Networks for Industrial Applications", *CCNC 2019*.

# Performance Evaluations

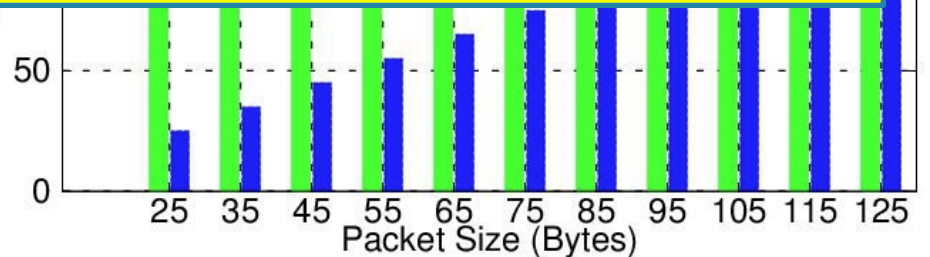


- Reduce energy consumption for sensors => more convenient for users
- Improve bandwidth utilization => add more sensors to the networks and transmit more data
- Our proposed approach significantly improves network performance in terms of energy efficiency, bandwidth utilization and throughput while guaranteeing delay requirements for industrial applications

[1] **N.Dinh**

Improving Performance of IEEE 802.15.4-based Home-Automated Systems", *Globecom 2018*.

[2] **N.Dinh** and P. H. Ha, "Advanced GTS Scheduling in IEEE 802.15.4 Networks for Industrial Applications", *CCNC 2019*.



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# Conclusions

- **Energy- Efficient Communications**

- Extend device lifetime without interrupting network operations
- Renewable Energy
- Wireless Power Transfer:
  - Allow energy charging in current wireless technologies

- **Bandwidth- Efficient Communications**

- Add more devices to the networks, backward compatibility with deployed products
- Improve CoE, network QoS

- **Applications**

- DAO projects
- CPS, IoT,...

**Thank you!**

**Q&A**