Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Network Merging :
                Design Strategies of An Ultra Low Power and High Reliability MAC]
Date Submitted: [12 March, 2009]
Source: [ShihHeng, Cheng and ChingYao, Huang]
        Company [National Chiao Tung University (NCTU), Taiwan]
Address [1001 University Road, Hsinchu, Taiwan 300, ROC]
Voice:[+886-919-572-936], FAX: [+886-3-572-2530], E-Mail:[fbil.ee91@gmail.com]

Re: [If this is a proposed revision, cite the original document.]

Abstract: [Network Merging , a WBAN-specific design strategy, is presented and analyzed. Without considering the unique features of WBAN, traditional wireless protocols fail the requirement and even induce negative impact. The unique features including the network mobility and imbalanced traffic loading are analyzed and corresponding design strategy, Network Merging, is suggested.]

Purpose: [Develop a Network Merging methodology for medical WBAN applications.]
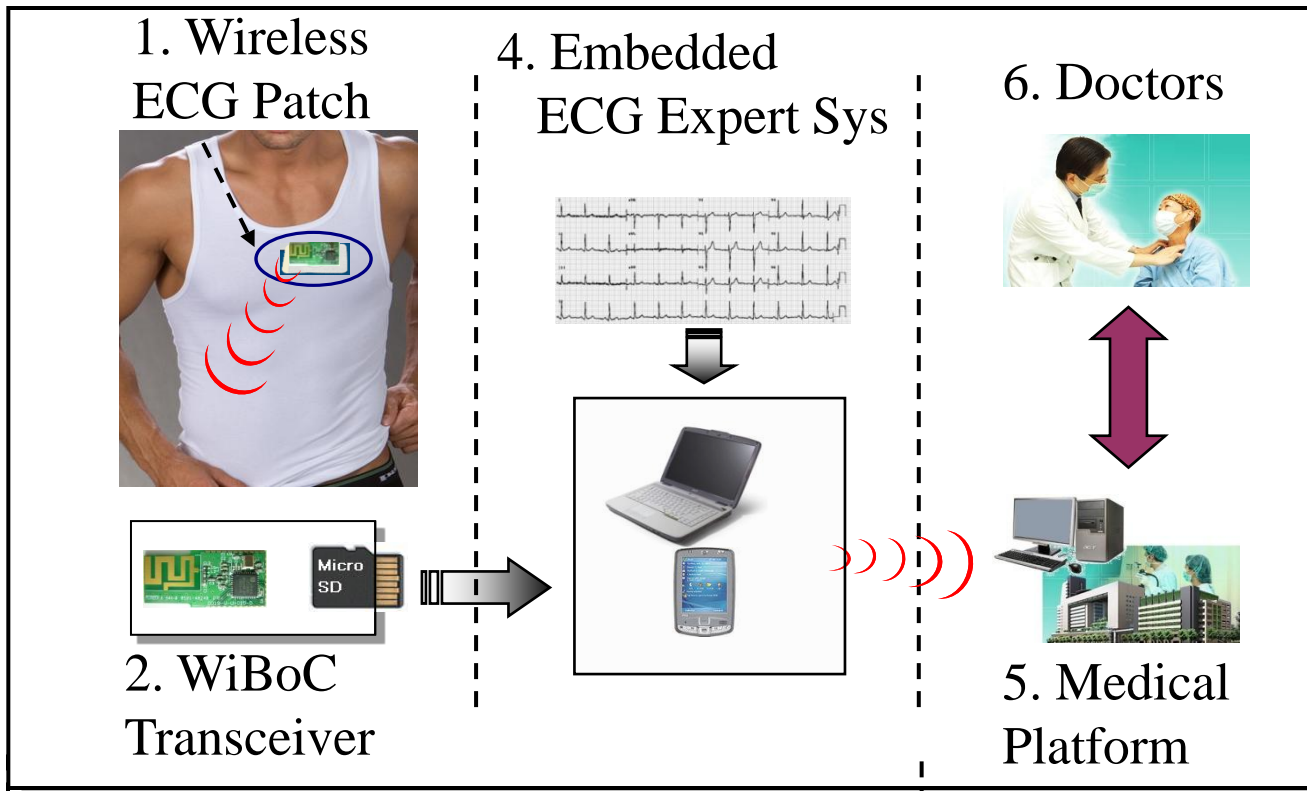
Network Merging

Design Strategies of
An Ultra Low Power and
High Reliability MAC

Outline

- U-PHI project, Taiwan
- Medical Wireless Body Area Network (WBAN)
- Requirements of medical WBAN
- Design strategy: Network Merging
- Evaluation of Network Merging
- Conclusion

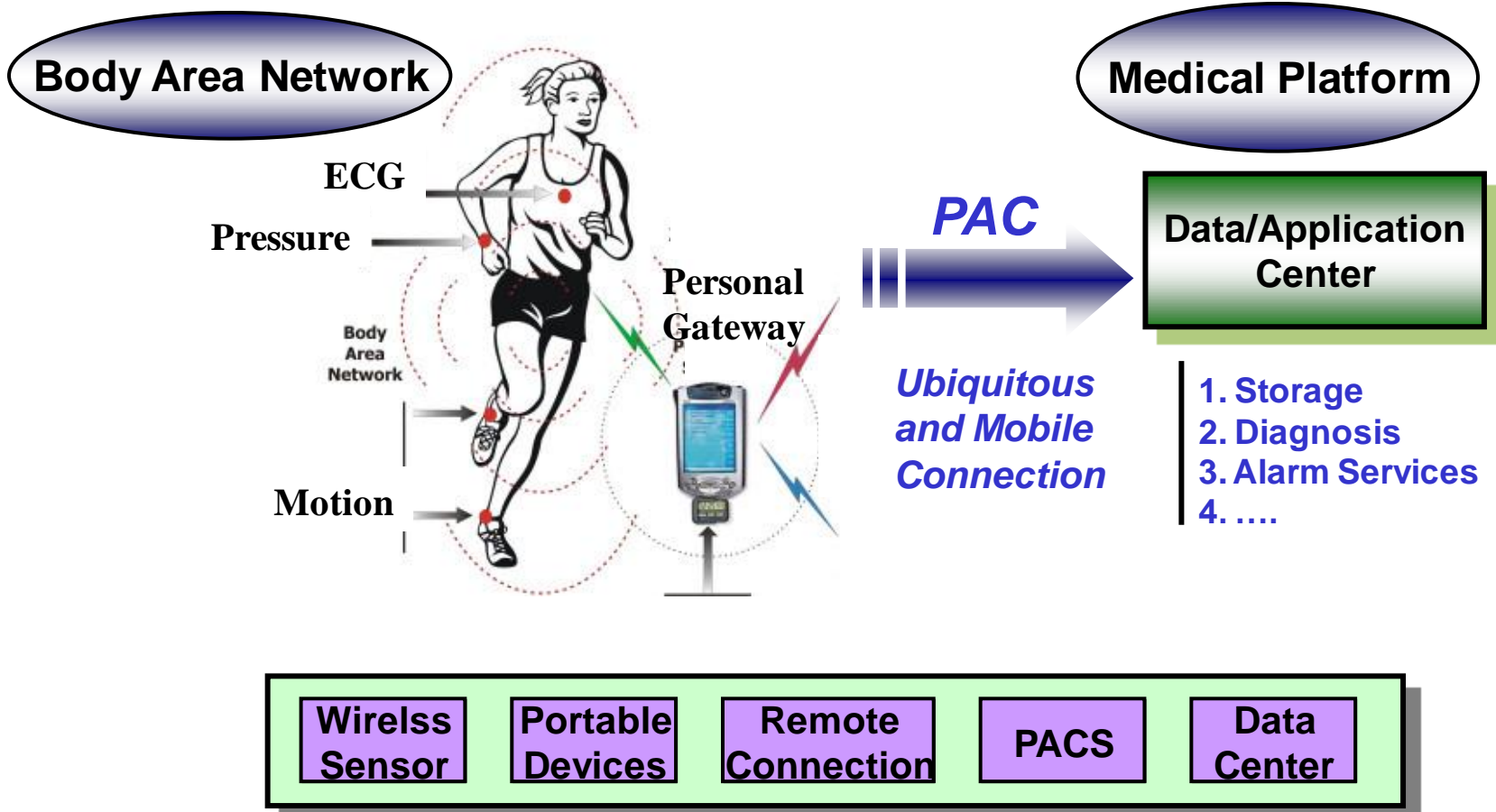# Ubiquitous Personal Healthcare Inspector (U-PHI) project, Taiwan

Leaders:

- CMUH Medical Platform
  Chair Ray-Jade Chen
- ECG Expert Sys
  Prof. Chin-Teng Lin
- Front-end Ckt
  Prof. Wei-Zen Chen
- Baseband Chip
  Prof. Chen-Yi Lee
- MAC protocol
  Prof. ChingYao Huang

Medical Wireless Body Area Network

Body Area Network

ECG

Pressure

Body Area Network

Personal Gateway

Motion

PAC

Data/Application Center

Medical Platform

Ubiquitous and Mobile Connection

1. Storage
2. Diagnosis
3. Alarm Services
4. ....

Wirelss Sensor	Portable Devices	Remote Connection	PACS	Data Center

Graph: E. Jovanov, A. Milenkovic, C. Otto, "A wireless body area network of intelligent motion sensors for computer assisted physical rehabilitation" in *Journal of NeuroEngineering and Rehabilitation*, 2005.

Requirements of medical WBAN

- ## Ultra Low power
  - – Tens of hours to years battery life time

**Endoscopy**
>12 hours

Pacemaker
>5 years

http://www.olympus-europa.com/endoscopy/2001_5491.htm
http://www.healthnode.org/tag/pacemaker/

Requirements of medical WBAN

- ## Who needs ultra Low power?
  - – End devices does.

- ## Energy efficiency of end device is more important than central device.
  - – User rather recharges specific device than all devices.
    - 🔴 Especially when number of devices > 24 (EEG, Neuron Apps)
  - – 🔴 Save the power of end devices!
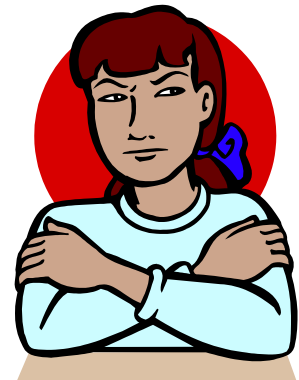
Requirements of medical WBAN

- ## High reliability (Qos of medical apps)

  - ### Definition? (#0644)
    $\Big\{$ Latency < 20ms ?
    Jitter < 2ms ?
    Reaction > 99.99% ?

    ✓Real-time Display

    ✓Lossless data storage

  - Sure thing :
    Both real-time & data integrity should be considered for medical traffic.
    🔴Medical traffic loading > Traditional Real & non-Real traffics

  - Need higher Channel efficiency
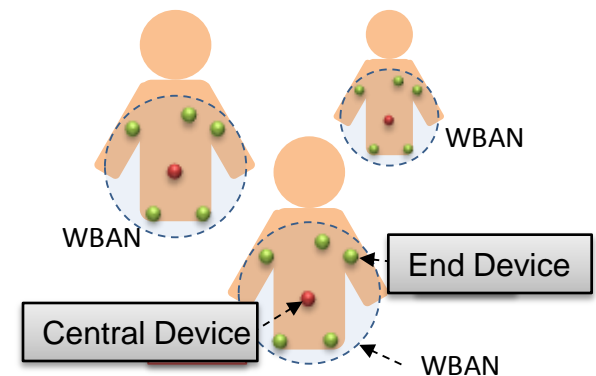   🔴 Avoid packet collision to increase capacity

Design strategy: Network Merging

- Network Merging is a <u>collision free</u> protocol, which promises up to
  4x user number increase &
  29% battery life time improvement.

That is,
5 simultaneous users → 20 users
30 days battery life → 40 days

Design strategy: Network Merging

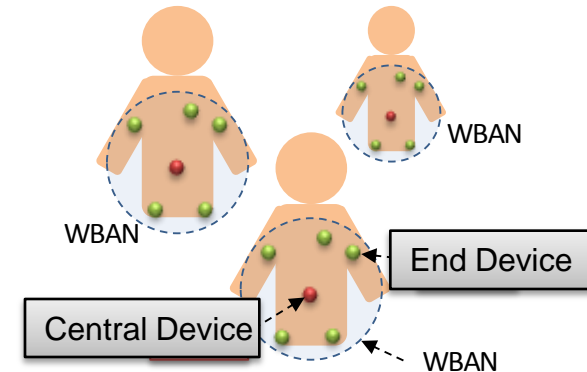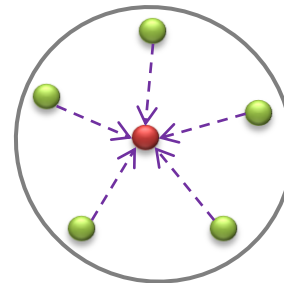- <u>Collision</u> is the major source of power consumption in WBAN.

Power waste in traditional sensor network

Overhearing
Idle listening ✖
Control message ✖
Packet collision ✔

Due to the "simple star" feature of WBAN

Design strategy: Network Merging

- **Simple Star Topology**
 - 3-5m radio range can cover most medical apps.
  - Upload-oriented traffic.

Power waste in traditional sensor network

Overhearing   Rx only! Not a problem of end device

Idle listening ∵End device is only a TX in most medical apps

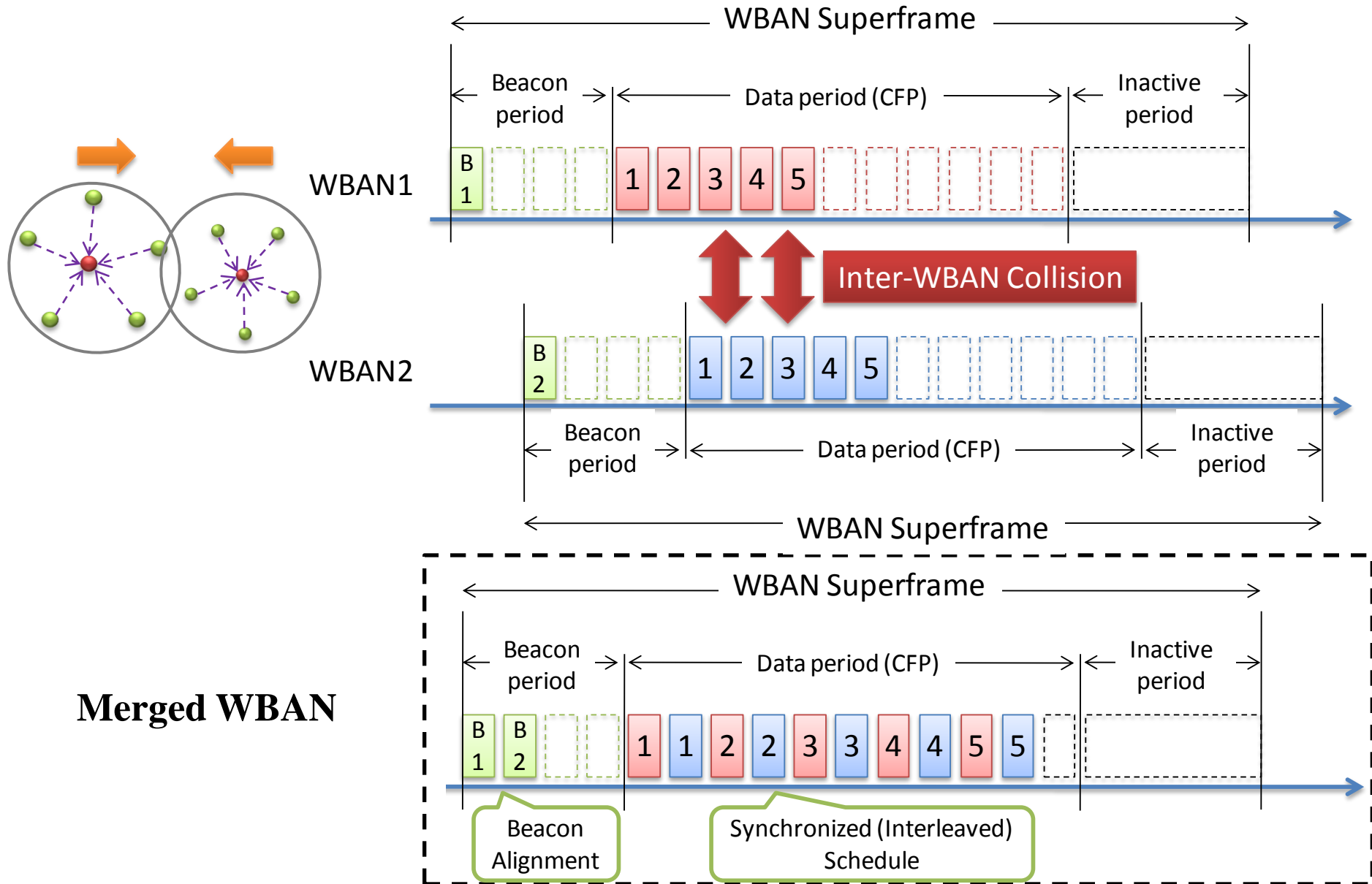Control message Assume traffic loading >> overhead

Packet collision

🔴 Collision is the major source of energy waste in WBAN!

How does Network Merging solve collision?

- Network Merging synchronizes the Tx schedules of multi-WBAN.
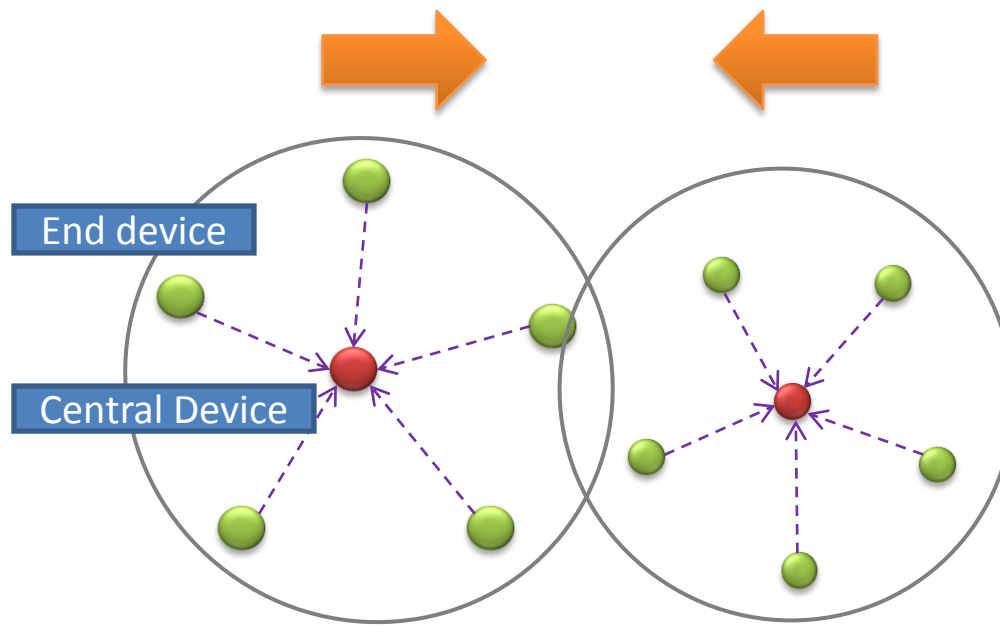
End device

Central Device

(1) Neighborhood discovery

(2) Schedule Synchronization

Merged WBAN

How does Network Merging solve collision?

- ## Why not Beacon or CSMA/CA? *

  (Beacon: cellular network, Bluetooth;
   CSMA: sensor, ad hoc, mesh networks)

  - ### CSMA/CA
    - ✔ Low Power
    - ✘ Poor channel efficiency

  - ### Beacon (Polling)
    - ✔ High channel efficiency
    - ✘ Very low power
      but suffers inter-network collision

> **Can not be used in high density WBAN.**

🔴 **240 sensors / elevator.**
(24 nodes ×10 people)

∗ ShihHeng, Cheng, ChingYao, Huang, Power model for wireless body area network, BioCAS, Baltimore, MD, Nov, 20-22, 2008

How does Network Merging solve collision?

- ## New collision source: inter-network collision. Reason: Moving network

  - WBAN moves with the position of user.

  - Traditional sensor network usually consider static or slowly move topology.

  - MANET considers "node" mobility. However, "network" mobility is more complex.
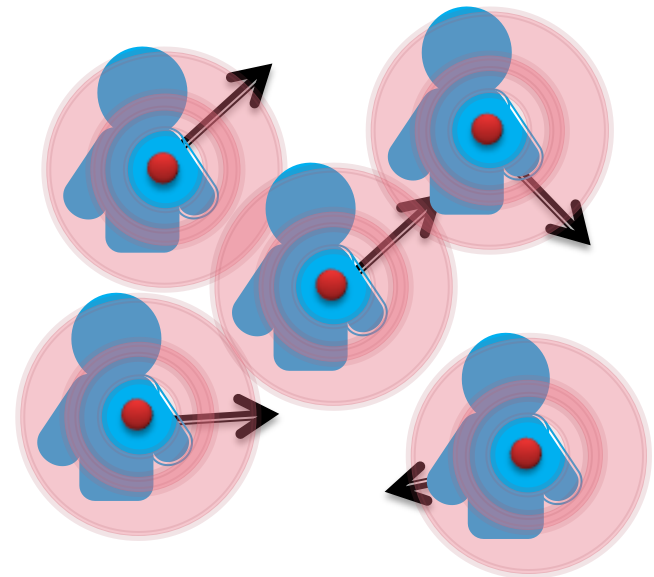
How does Network Merging solve collision?

- Network Merging overcomes both intra & inter network collision.

Inter: Schedule alignment

Intra: Beacon
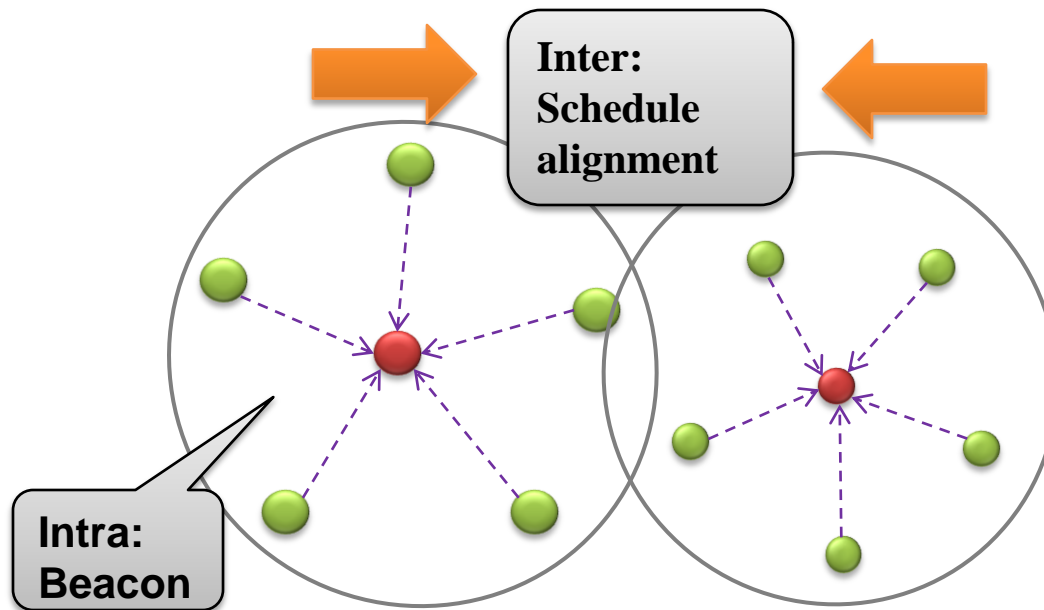
(1) Neighborhood discovery

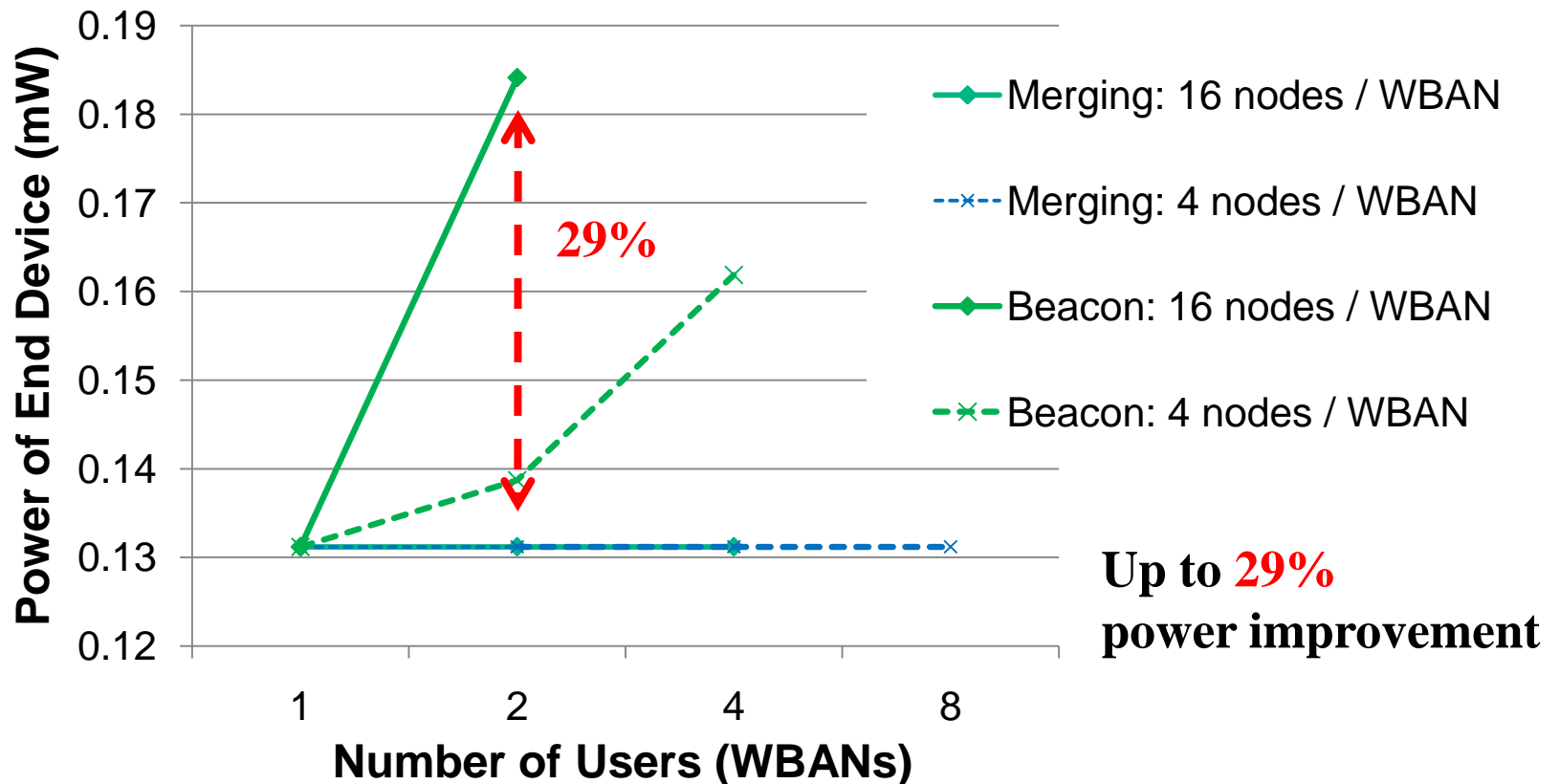(2) Schedule Synchronization

Evaluation: Network Merging

- **Power Model for Wireless Body Area Network**∗

  – Topology
    Multi-WBAN

  – Beacon size / Packet size / Traffic loading / PHY speed
    0.2kb / 8kb / Uplink 8kbps ECG for each WSN / 625kbps

  – Power consumption
    Tx, Rx: 10mW / Sleep: 0mW

  – Access control
    Beacon (polling) , CSMA/CA, & Network Merging

  – Collision
    Intra & inter network collision (IANC & IRNC)

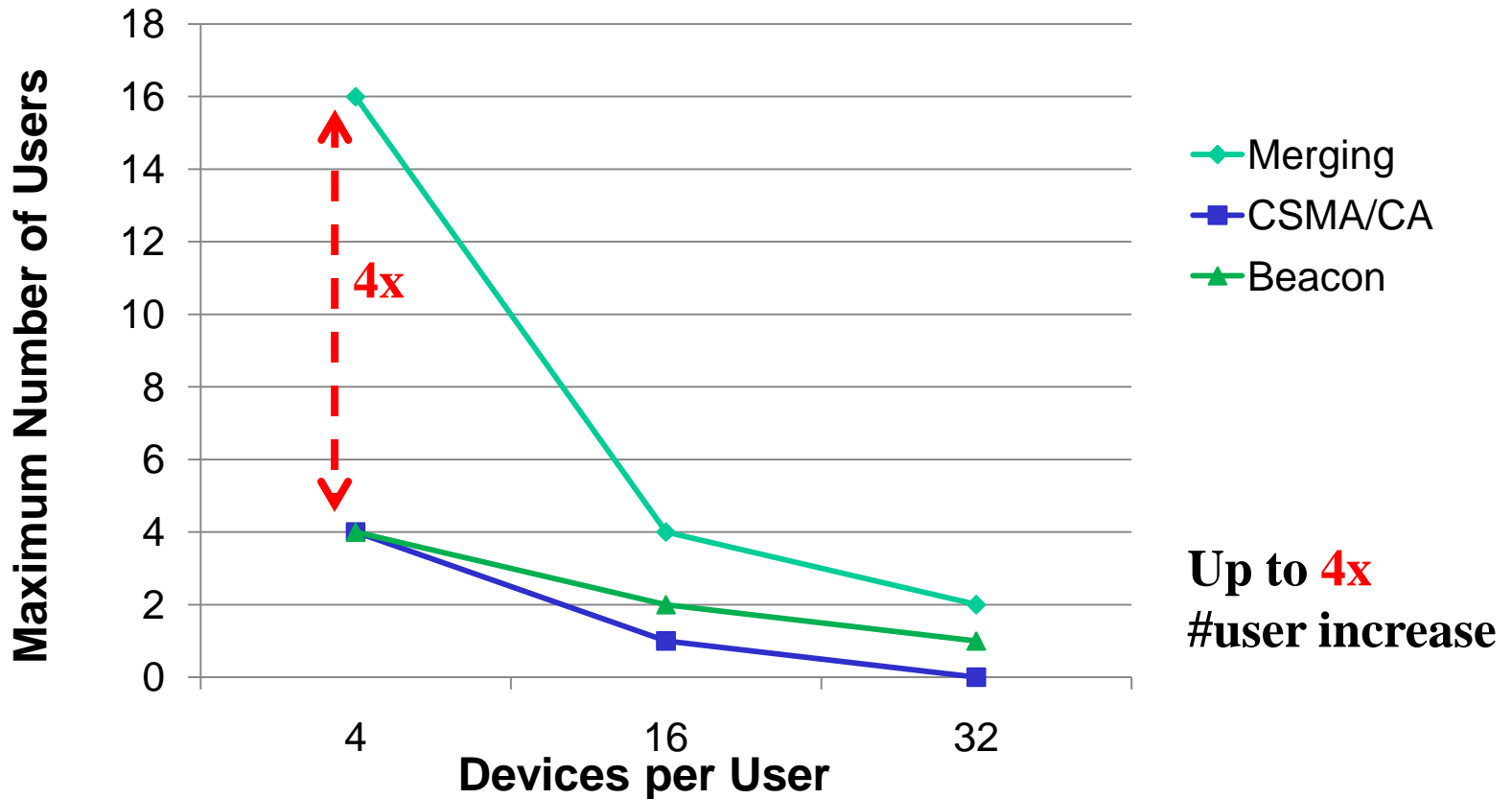∗ ShihHeng, C.,ChingYao, H., Power model for wireless body area network, BioCAS, Baltimore, MD, Nov, 20-22, 2008

Evaluation: Network Merging

- Synchronize Tx schedules of multiple WBANs

Up to 29% power improvement

Evaluation: Network Merging

• Synchronize Tx schedules of multiple WBANs

Up to **4x** #user increase

Open issues

- ## Direct or Assisted network merging?

Path of Inter-network communication

For the exchange of Tx schedule & neighbor list

End device

Central device

Major base station

Mobile Femto cell

(a)

(b)
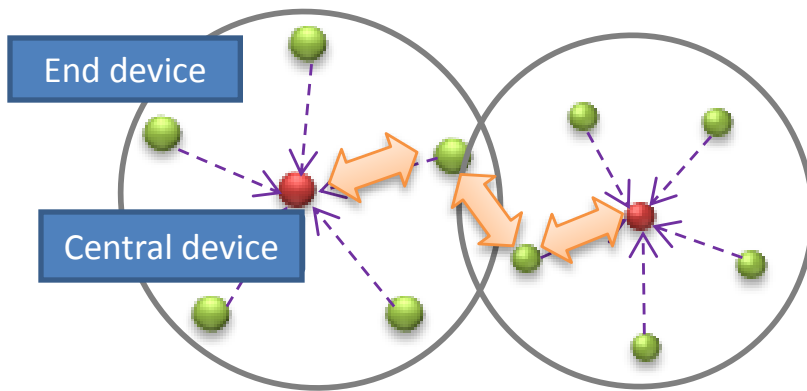
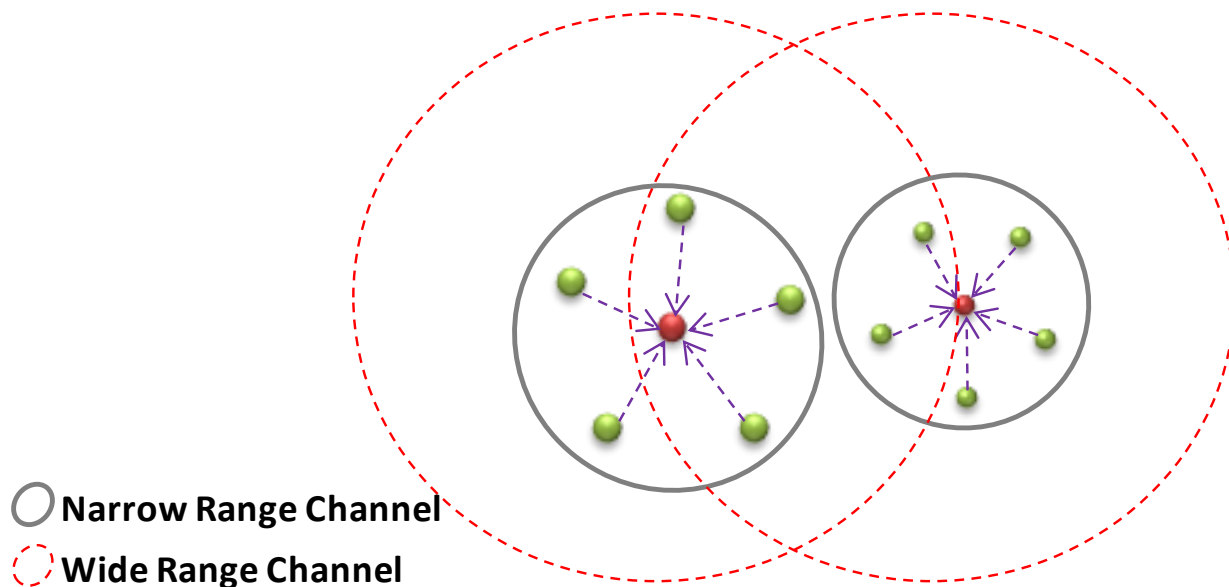**Direct network merging**

❌ Routing overhead of end device
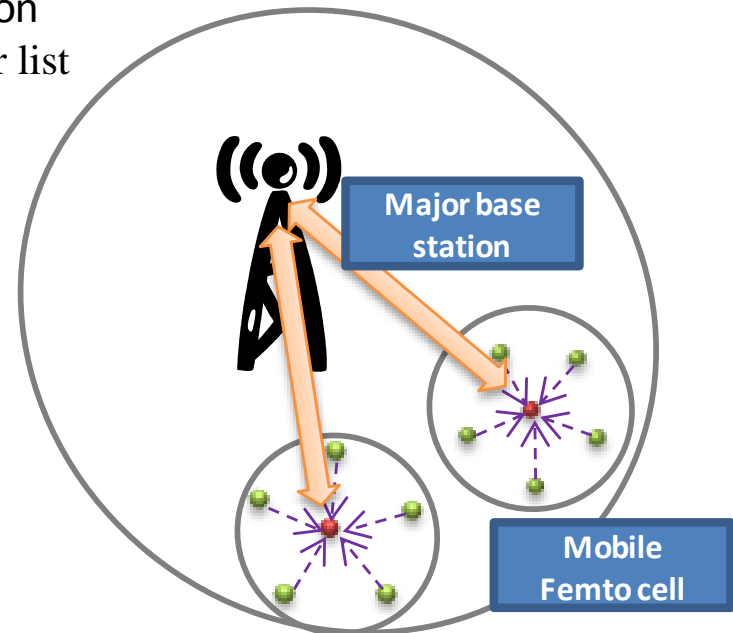
Assisted network merging

❌ Accurate (meter-level) localization

Proposed network merging

- Any better approach? Seamless network merging
  - Central node has two radio ranges (Narrow & Wide)
    - Narrow range channel (NRC): for intra-WBAN communication
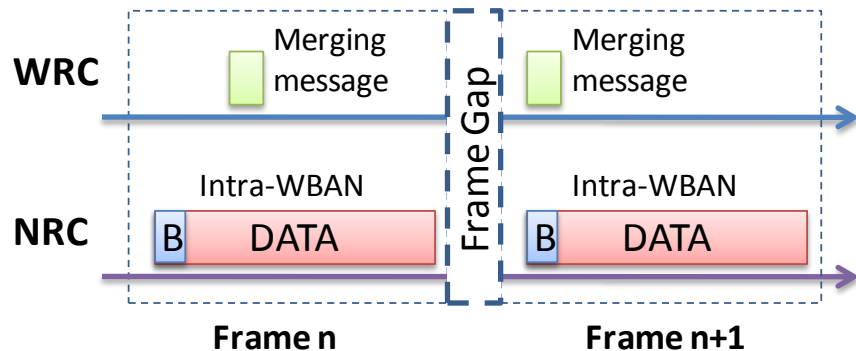   - Wide range channel (WRC): for inter-WBAN communication

⬭ **Narrow Range Channel**

⬭ **Wide Range Channel**

Proposed network merging

- ## Possible structures of seamless network merging

Parallel structure
•**Two independent PHYs**
•**Synchronized PHYs**

Serial structure
•**Single PHY**
•**Dynamic Tx power**
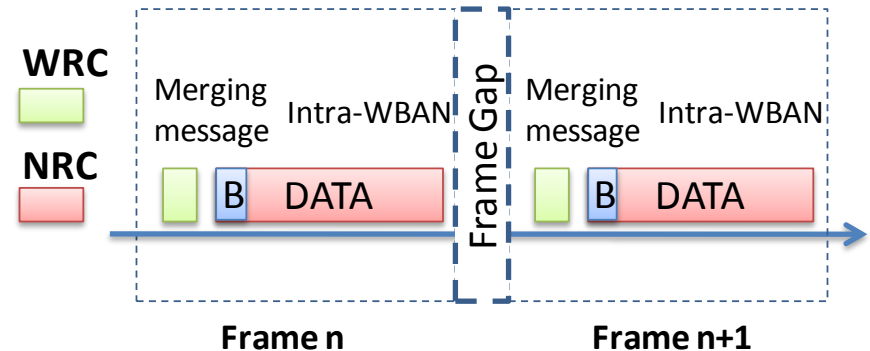
*Frame gap comes from the beacon re-alignment

Overview of network merging

Advantage	Approach	Comparison with traditional solutions	Open issues
Optimize both power efficiency & channel capacity.	Solve the inter-WBAN collision by neighbor discovery and schedule negotiation.	● Beacon: very low power efficiency ● CSMA/CA: very low channel utility	Tradeoff between direct and assisted inter-WBAN communication. **Proposed seamless network merging**

Conclusion

- Two major requirement:

  – low power & high reliability

- Two unique features:

  – Simple Star & Moving Network

- Network Merging

  – Solve intra & inter network collision
    Meet two major WBAN requirements.

  – Proposed seamless network merging

- Welcome for any cooperation!
  (Optimized single network solutions & any PHY)

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