Heterogeneous Integration Roadmap (HIR)

6th Annual Conference February 22 -24, 2023

HETEROGENEOUS INTEGRATION ROADMAP

Two days Conference Program – February 23 Day 1

HIR Group 2 :

(14:40 am – 16:00 pm, Pacific)

14:40 + 10 min	Medical, Health & Wearables: Mark Poliks (Binghamton University), Nancy Stoffel (GE), Jan Vardaman (TechSearch)
14:50 + 10 min	**IoT: Robert Lo (ITRI Taiwan) Rockwell Hsu (Cisco)**
15:00 + 10 min	Simulation: Chris Bailey (Arizona State U), Xuejun Fan (Lamar University)
15:10 + 10 min	Reliability Abhijit Dasgupta, Richard Rao (Marvel) & Shubha Sahasrabudhe (Intel))
15:20 + 10 min	Emerging Research Devices: Meyya Meyyapan, Bill Bottoms (3MTS)
15:30 + 30 min	Group 2 Cross TWG Dialogue & Q&A

IoT: Robert Lo (ITRI), Rockwell Hsu(Cisco), Bill Chen (ASE)

Internet of Things (IoT) Chapter

Presenter: Wei-Chung(Robert) Lo, TWG Chair

Deputy General Director of Electronic and Optoelectronic System Research Laboratories(EOSL) of ITRI

Dr. Lo received his Ph.D. from National Taiwan University and joined Industrial Technology Research Institute to work in advanced electronic packaging, such as WLP, 3D IC/3D stacking, fan-out, heterogeneous integration technology for more than 20 years, 85 papers and 27 patent granted.

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Internet of Things (IoT) Chapter

Dr. Rockwell Hsu is a Technical Lead at Cisco Systems, Inc. where he leads an initiative on advanced semiconductor packaging development for 112Gbps per lane signaling for network equipment and SI/PI development for network line cards and fabric cards used in switches and routers. Prior to Cisco, he led RF and server CPU packaging development at Intel. Dr. Hsu holds one US patent.

Industry advisor for NSF's Convergence Accelerator – 2022 Cohort, Track I.

Active Thrust 4 member in Southeastern Consortium for Assured and Leading-Edge Semiconductors (SCALES)

Dr. Hsu was the chair of the High-Speed, Wireless & Components Committee for the IEEE Electronic Component Technology Conference (ECTC) and has been a member of the ECTC since 2006.
Dr. Hsu was the chair of Santa Clara Valley Chapter of the IEEE Antennas and Propagation Society (APS).

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[Executive Summary of 2021 IoT Chapter]

From World Health Organization,, more than 650 million COVID-19 confirmed cases (compared to 80M December, 2020; 290M December, 2021) all over the world by the end of December in 2022 …. the the post-COVID-19 period…. The accelerated adoption of digital technologies and continued remote working required more and more IoT usages.

Here in this revised version, new electronic packaging technique achievements, such as double sided SiP for IoT and 5G application. In addition, various LPWAN standards for different applications of IoT power consumption….. Some more IoT platform cases including AI box/Gateway … to provide an innovative AI motor fault pre-diagnosis product for Industrial IoT(5G).

According to the report of Cisco, **500 billion devices** are expected to be connected to the Internet **by 2030**

- Each device includes sensors that collect data, interact with the environment, and communicate over a network.
- These smart, connected devices generate **data** that IoT applications use to aggregate, analyze, and deliver insight, which helps drive more informed **decisions and actions**.

- **Benefits IoT**
- **Challenges for IoT**
- **Difficulties technical issues**
- **Convergence of AI and Big Data and IoT**
- **Examples of Heterogeneous Integration Solutions for IoT**
- **IoT Ecosystem and Heterogeneous Integration Influence in HI Technologhy Development**
- **Future of IoT**

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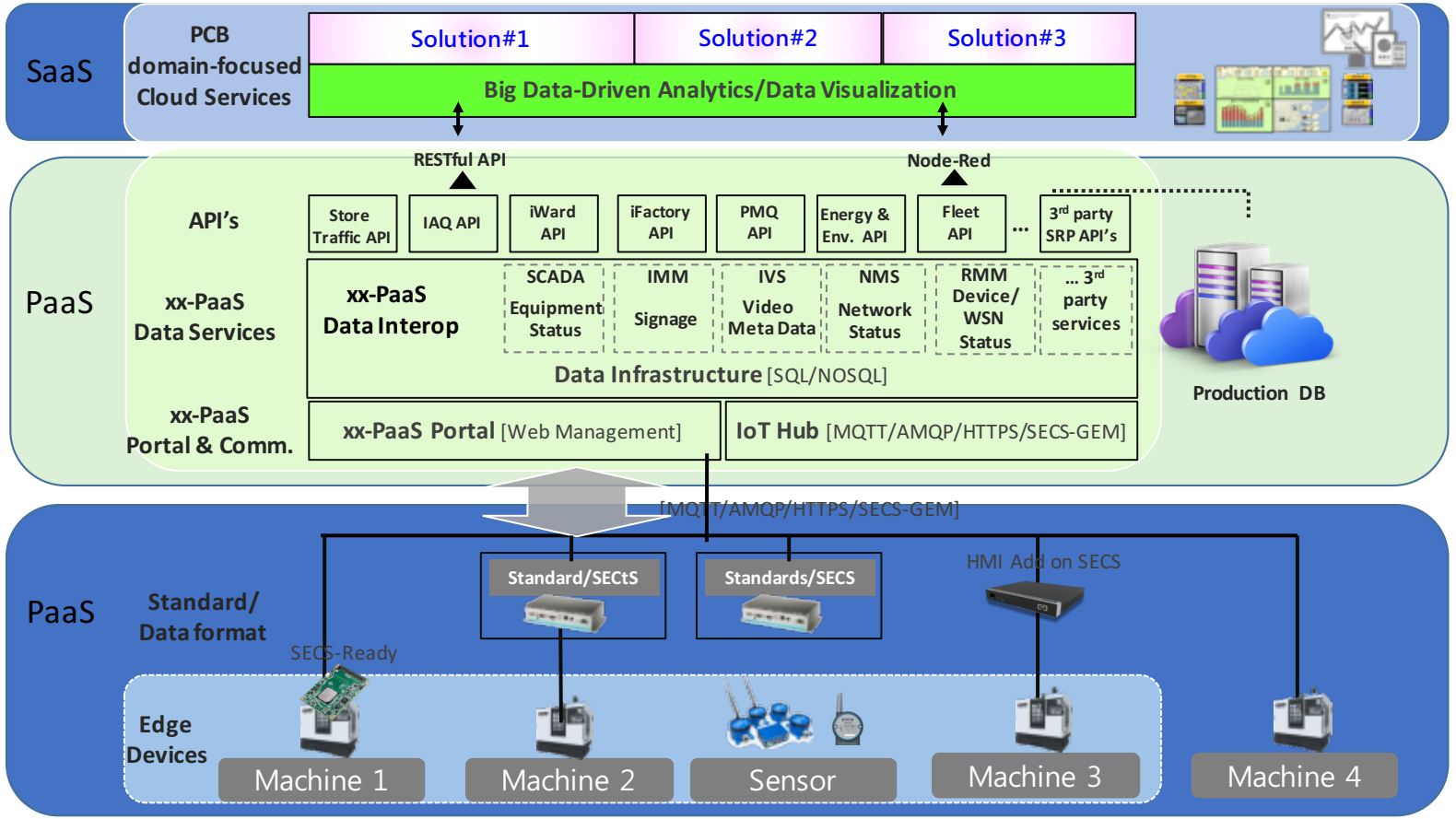
Building up an Industrial IoT Co-Creation Business

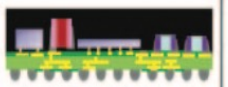
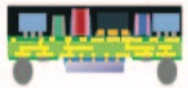
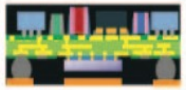
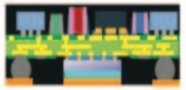
PCB Domain-Focused Cloud Services



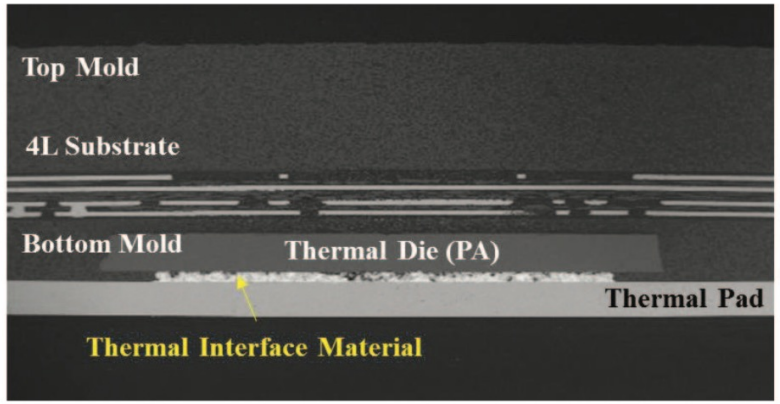
- **Examples of Heterogeneous Integration Solutions for IoT**
  [Can refer to other TWG chapter for 2D/3D, SiP, WLP, 5G, etc for good examples of the HI solutions for IoT.]
  A. Connectivity
  B. Autonomous IoT system
  C. Edge AI device
  D. IoT for Wearables
  E. Integrated sensor packaging
  F. Heterogeneous Integration of IoT Basic Elements
  G. Thin-Film battery for IoT microsystems
  H. Senor platform for IoT medical applications
  I. Double Side SiP for IoT and 5G Application
  J. Wafer-level Packaged Gauge for Industrial IoT (IIoT) Application

I. Heterogeneous Integration of Double Side SiP for IoT and 5G Application

- Double Side SiP: dual side molding to shrink size.
- The calculation of package size can be reduce over 40% PCB placement area from 8 x 8mm to 6 x 6mm.
- Advantage: simplify PKG I/O Count (10% reduction), power supply efficiency and reduce noise emission.
- For electrical, better electrical performance (SI & PI) than other side by side flip chip base structure.
- For thermal performance, high thermal solution can be improved 24~38%...

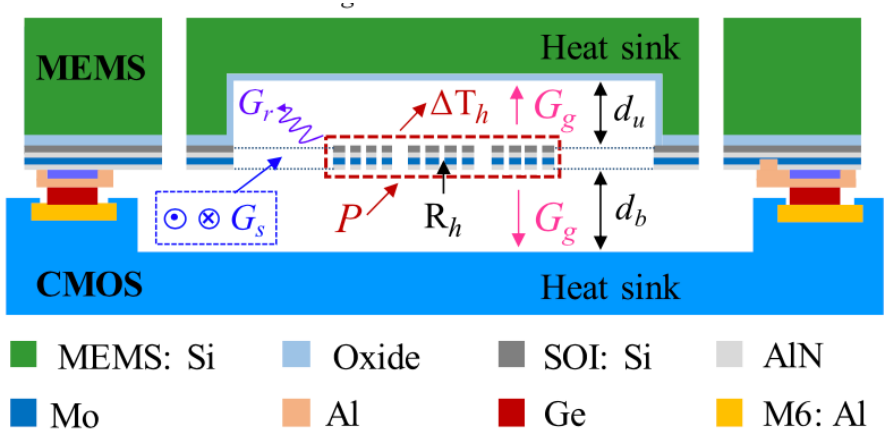
Item	Structure 1	Structure 2	Structure 3	
Purpose	Single Side	Double Side	Double Side Molding	Double Side Molding + Thermal Enhance
Package Structure				
PKG Size	100%	Reduce 40~60%		
Thermal Solution	NA	NA	Add Thermal Pad	Add Thermal Interface Material

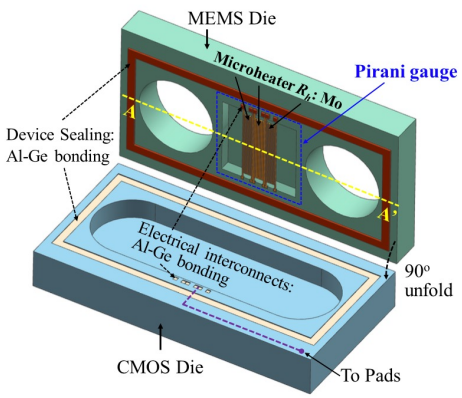
Comparison of SiP structure (Single & Double Side SiP)

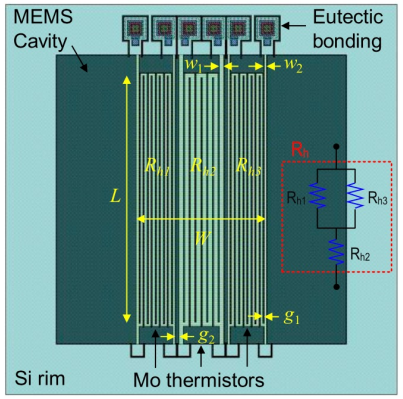


J. Wafer-level Packaged Gauge for Industrial IoT (IIoT) Application

- A WL packaged Pirani vacuum gauge using the InvenSense CMOS MEMS technology
- 3 serpentine-shaped Mo thermistors on suspended SOI bridges, while the wiring gap of each serpentine- shaped silicon microbridge is 1.6 μm.
- Significantly reduced footprint: the measured range of 5×10^{-4} –760 Torr.
- A promising Internet of Things (IoT) sensing node for vacuum monitoring in the industry.

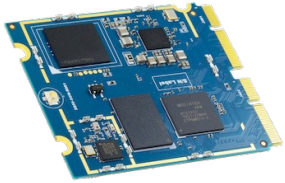


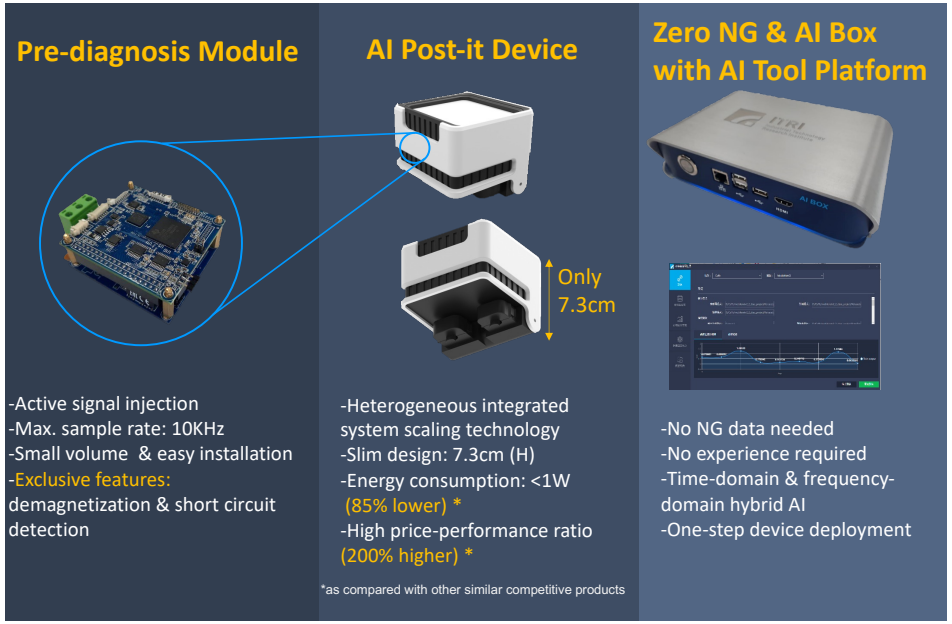


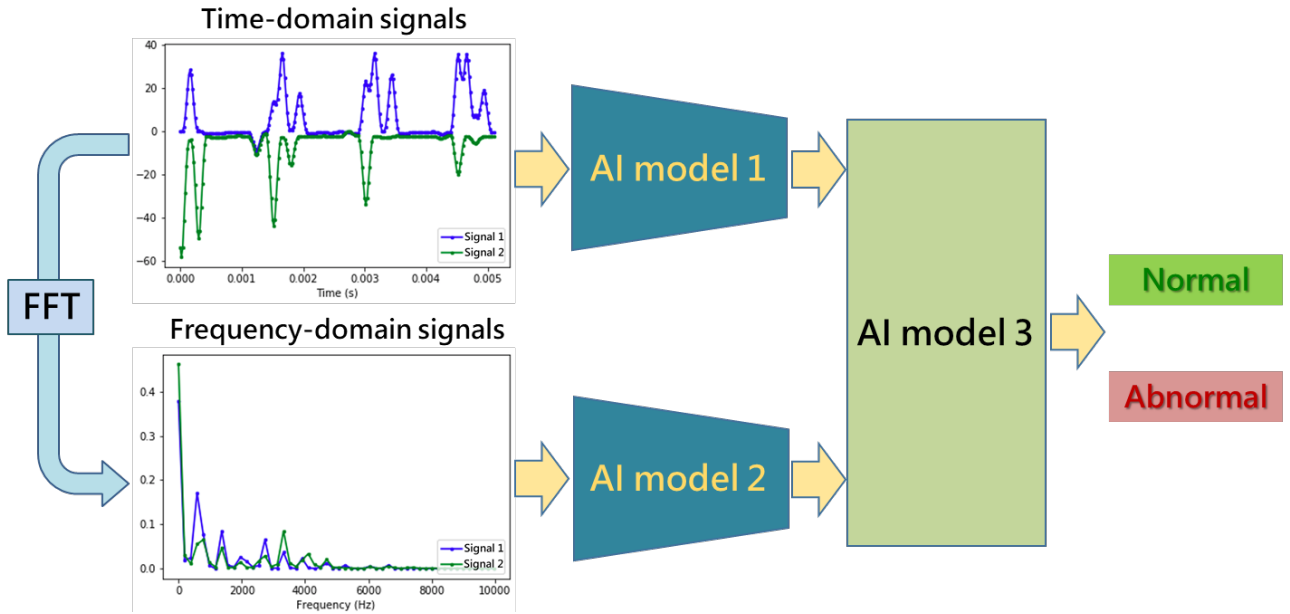


IEEE Trans. Electron. Devices, vol. 68, no. 10, pp. 5155–5161, October 2021

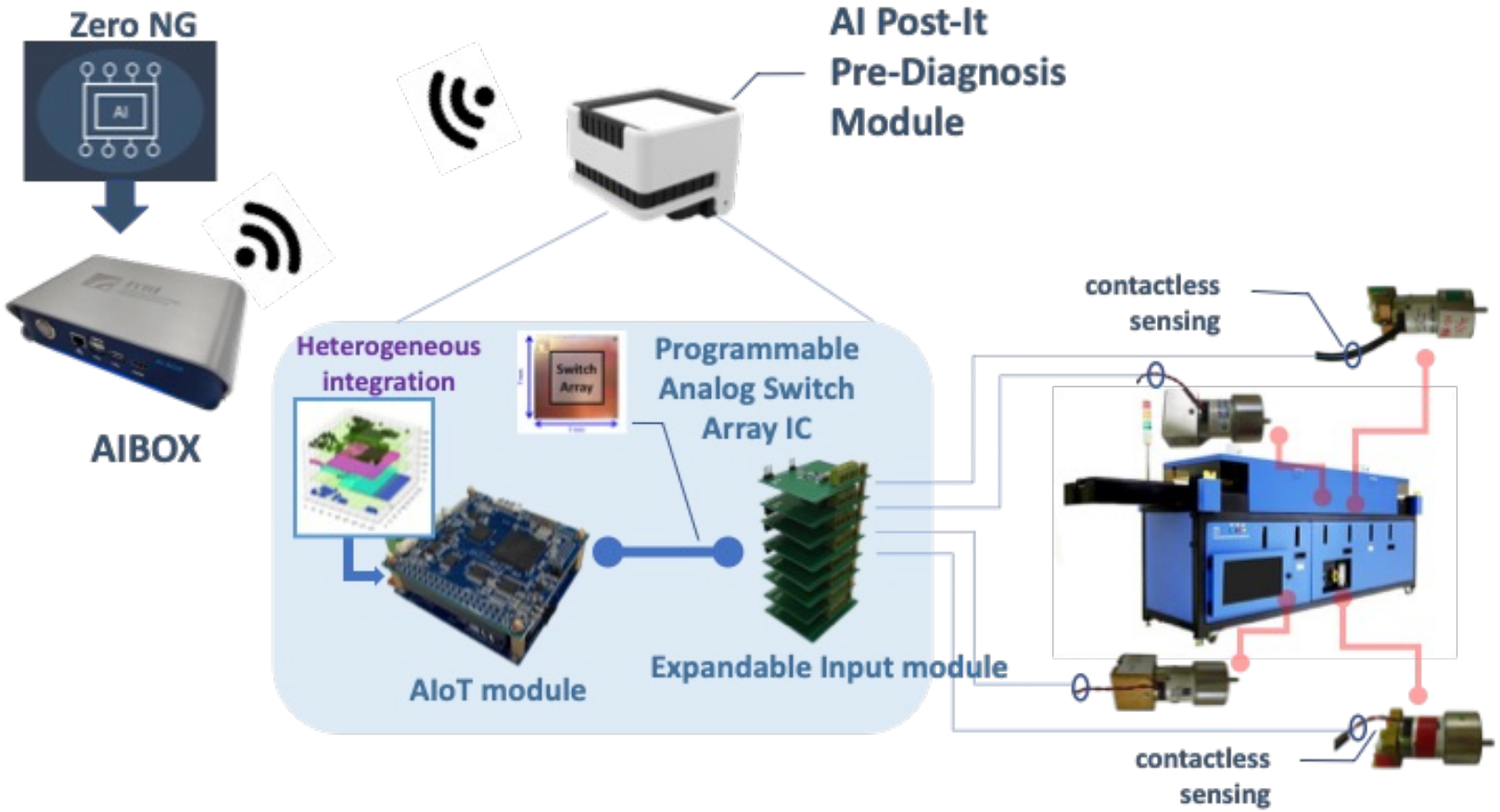
- AIoT platform I: for smart home, smart city and smart factory
- AIoT platform II: IoT based Smart Healthcare Monitoring Systems (overview)
- **AIoT platform III: Private 5G/Local 5G to meet IIoT applications**







AIoT platform III: Private 5G/Local 5G to meet IIoT applications



- Programmable Analog Switch Array IC monitors up to 50 motors
- AIoT edge computing: data no longer transmitted to the cloud for processing and analysis.
- Key innovative designs include a Zero NG deep neural network and a non-intrusive pre-diagnosis module.
- Less energy offering alert to motor failures with 24/7 condition monitoring & fault pre-diagnosis

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2023 IoT Chapter (possible) plans:

- **Specified application requirements input and HI technology solutions**
  - **MORE** ”real” IIoT systems deployed by adopting “Local or private 5G”
  - Unique requirements for IIoT & IoMT applications with “Heterogeneous Integration” technology
  - Hardware security: physical attack protection techniques for IC Chip & HI Level
- **More discussing with other chapters(cross-TWG)**

Acknowledge

Internet of Things Technical Working Group Membership

The TWG would like to thank the cooperation and supports in all the contributors as below, especially greatly appreciate for Dr. Chih-I Wu, General Director of Electronic and Optoelectronic Systems Research Laboratories (EOSL)/ITRI.

Key Contributors:

- Wei-Chung (Robert) Lo, ITRI, Chair
- Bill Chen, ASE
- Rockwell Hsu, Cisco
- Sebastian Liau, TUSA/ITRI
- …New members
- Chih-I Wu, EOSL/ITRI
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- Harrison Chang, ASE
- CK Chung, SPIL
- Gamal Refai-Ahmed, Xilinx
- Robert Kao, NTU
- Li Li, Cisco
- Chi-Hsin Yang, ISTI/ITRI
- Che-Hao Fan, ISTI/ITRI
- Bor-Feng Jiang, ISTI/ITRI
- ….

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Thank you For Your Attention

Internet of Things (IoT) Technical Working Group will need YOUR PARTICPATION!

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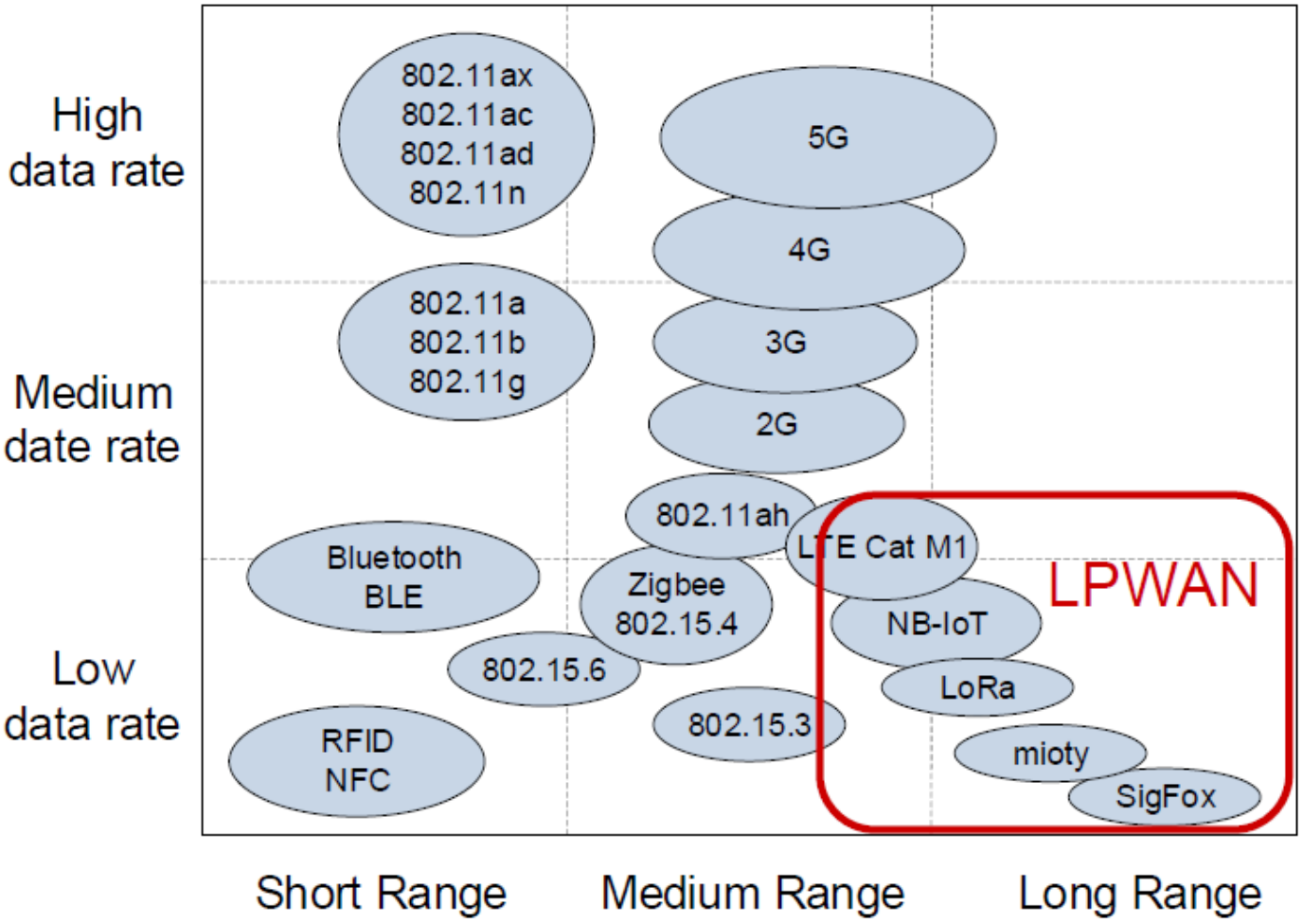


For home applications (LPWAN):

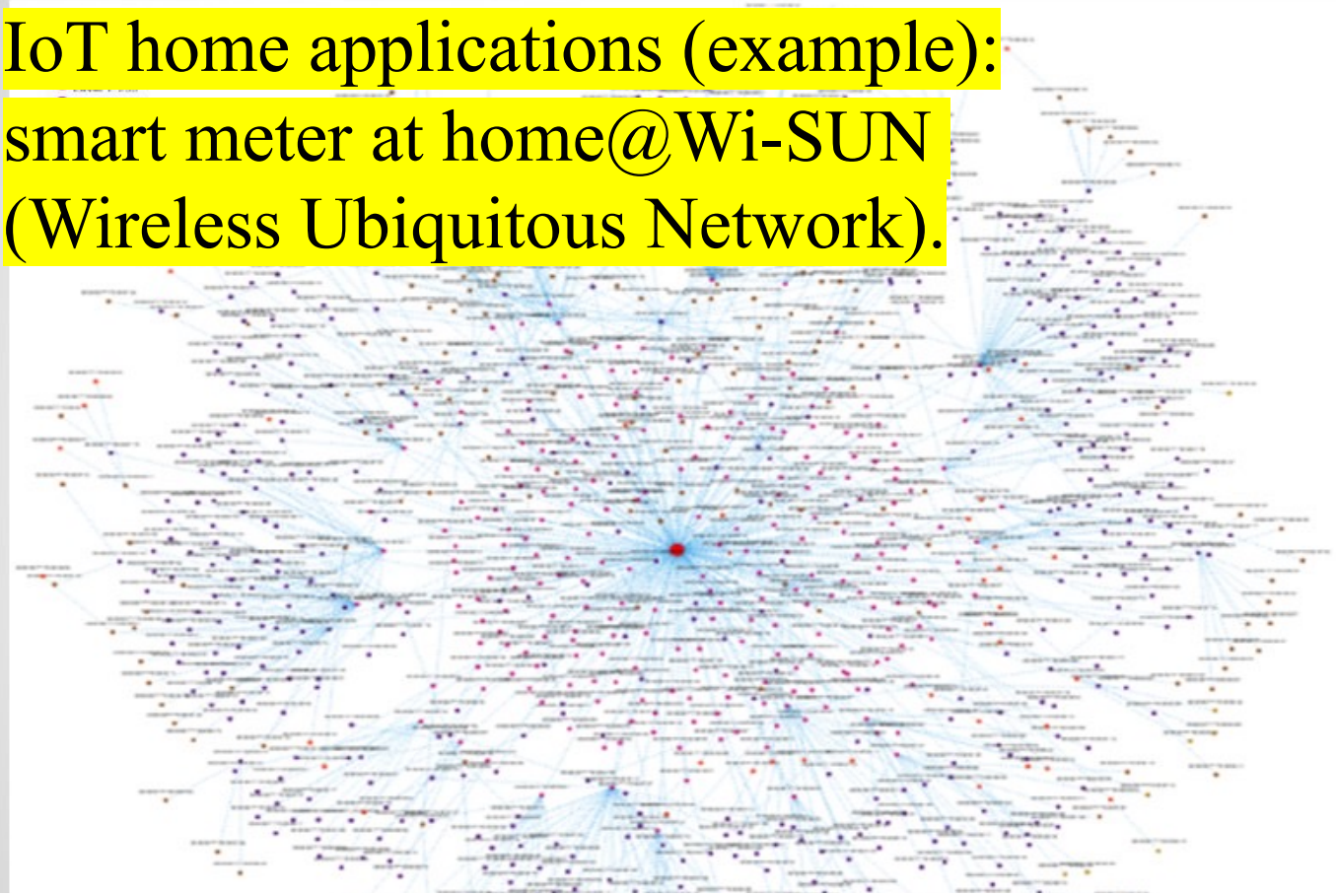
- for the remote sensors far away from edge devices like smart grid, there are two major challenges: range > 1km and low power < 100uW.
- Low power is critical for battery operated remote sensors to avoid replacing battery too often to lower the maintenance cost.
- Typically, 10 years of battery life is desirable to deploy thousands of remote sensors, and low power means sensors may transmit at very low data rates like few bytes per day.
- To meet these challenges, a low power wide area network (LPWAN) standard is needed to support industrial and infrastructure applications

Source: Rockwell Hsu, Cisco

1st to Achieve 1000 Nodes Mesh Based on Wi-SUN FAN1.0

VertexCom

IoT home applications (example):
smart meter at home@Wi-SUN
(Wireless Ubiquitous Network).



	1000 pcs, 6 Hops		
	Test 1	Test 2	Test 3
100	0:04:35	0:05:23	0:03:43
300	**0:08:09**	**0:08:57**	**0:07:17**
500	0:12:56	0:13:44	0:12:04
800	0:20:56	0:21:44	0:20:04
1000	**0:31:03**	**0:31:51**	**0:30:11**

- 1000 Nodes Networking Time, 129 channels
  - 20 min. for 1 hop
  - 30 min. for 6 hops
- Meter Reading Success Rate
  - 99.36% of 191,909 times w/o resend
- Push Mode Success Rate:
  - 500 Byte Data
  - 99.82% in 15 min. w/o resend