ArchSummit全球架构师峰会北京站2015

Wi-Fi SoC 芯片在IoT智能设备中的应用

Frank Huang

Marvell Semiconductor Inc.

Geekbang.
极客邦科技

整合全球最优质学习资源，帮助技术人和企业成长

Growing Technicians, Growing Companies

InfoQ queue

专注中高端技术人员的
技术媒体

EGO EXTRA GEEKS' ORGANIZATION NETWORKS

高端技术人员
学习型社交网络

StuQ queue

实践驱动的
IT职业学习和服务平台

GiT GEEKBANG INTERNATIONAL TRAINING 极客邦培训

一线专家驱动的
企业培训服务

地址：北京市朝阳区洛娃大厦C座6层1607室　　网址：www.geekbang.org

提纲

- **IOT智能设备的连接技术及其发展趋势**
  - Wi-Fi
  - Bluetooth Smart
  - Z-Wave
  - ZigBee
  - Thread
- **IOT设备的 Wi-Fi SoC 智能技术方案**
  - 集成方案 (Highly Integrated SoC)
  - 智能设置 (Smart Configuration)
  - 省电优化 (Power Saving Optimization)
  - 桥接技术 (Bridge for Mesh)
  - 自动互联 (Auto Link in Mesh)

提纲

- **IOT智能设备的连接技术及其发展趋势**
  - Wi-Fi
  - Bluetooth Smart
  - Z-Wave
  - ZigBee
  - Thread
- **IOT设备的 Wi-Fi SoC 智能技术方案**
  - 集成方案 (Highly Integrated SoC)
  - 智能设置 (Smart Configuration)
  - 省电优化 (Power Saving Optimization)
  - 桥接技术 (Bridge for Mesh)
  - 自动互联 (Auto Link in Mesh)

IOT智能设备的连接技术

Wi-Fi

- A.K.A Wireless LAN
- Based on IEEE 802.11 MAC/PHY Specification
- 802.11b(1999)/g(2003)/n(2009)
  - Running at 2.4 GHz
  - Rate up to 150 Mbps for 1X1 at 40 MHz bandwidth in 11n
- 802.11a(1999)/n(2009)/ac(2013)
  - Running at 5GHz
  - Rate up to 867 Mbps for 1X1 at 160 MHz bandwidth in 11ac
- 802.11ad (WiGig®, 2012. Merged with Wi-Fi in 2013)
  - Running at 60 GHz
  - 6.75 Gbps
- 802.11af (White-Fi/Super Wi-Fi, 2014)
  - Running on white space spectrum in the VHF/UHF bands between 54 and 790 MHz
  - Rate is 26.7 Mbps for 6/7 MHz channels and 35.6 Mbps for 8MHz channel
- 802.11ah (Est 2016)
  - Low power and range up to 1km
  - Running at 900 MHz
  - Rate at least 100 Kbps
- 802.11ax (early stage)
  - Based on 802.11ac
  - Running at 5GHz
  - Significantly improved throughput in dense deployments

Bluetooth Smart

- A.K.A Bluetooth Low Energy (BLE)
- Based on Bluetooth 4.0 standard released in 2010
- Enhanced in version 4.1 and 4.2
- For low power devices like healthcare, fitness, wearable etc.
- Not backward compatible with classic Bluetooth protocol
- Running at 2.4 GHz
- Rate 1Mbps

Z-Wave

- Proprietary design (from Sigma Designs Inc.)
- Low power
- For battery-operated devices like smoke alarms, security sensors etc.
- Running at 900 MHz
- Rate up to 100 kbps

ZigBee

- Based on IEEE 802.15.4 ratified in 2004
- Conceived in 1998, standardized in 2003 and revised in 2006
- Mesh network topology (OK with Star and Tree)
- ZigBee PRO (A.K.A ZigBee 2007)
  - Backward compatible with ZigBee 2006 devices
  - Enhanced routing process
- ZigBee IP (ZIP, 2014)
  - IPv6
  - Over 6LoWPAN
- Up to 65K devices per network
- Low Cost, Low Power
- Running at 2.4GHz globally
- Rate up to 250 kbps

Thread

- Alliance initiated by Google® in July 2014
- Running on existing 802.15.4 silicon
- Stack based on 802.15.4-2006 version
- UDP with IPv6
- Over 6LoWPAN
- Up to 250 devices per network
- Designed for very low power operation
- Running at 2.4GHz
- Rate up to 250 kbps

连接方案比较

	Wi-Fi	BLE	Z-Wave	ZigBee	Thread
Indoor Range	>50m	50m	30m	10-20m	10-20m
Max # of device	Implementation dependent	Implementation dependent	232	65K	250
Data Rate	>1Gbps	1Mbps	100 Kbps	250 Kbps	250 Kbps
Frequency	2.4 GHz /5GHz	2.4GHz	908/916 MHz (U.S)	2.4GHz	2.4 GHz
Mesh Support	Yes*	No*	Limited	Yes	Yes
IP Support	V4/V6	V4/V6	No	V6*	V6
Low Power	No*	Yes	Yes	Yes	Yes

结论

	Wi-Fi	BLE	Z-Wave	ZigBee	Thread
Well Deployed?	✓	✓	x*	✓	x
High Throughput?	✓	x	x	x	x
Long Range?	✓	✓*	x	x	x
Internet Connection?	✓	x	x	✓*	✓
Power Friendly?	x*	✓	✓	✓	✓
Good Roadmap?	✓	✓	x	✓	✓

Wi-Fi is still a GREAT solution for IOT

提纲

- IOT智能设备的连接技术及其发展趋势
  - Wi-Fi
  - Bluetooth Smart
  - Z-Wave
  - ZigBee
  - Thread
- **IOT设备的 Wi-Fi SoC 智能技术方案**
  - 集成方案 (Highly Integrated SoC)
  - 智能设置 (Smart Configuration)
  - 省电优化 (Power Saving Optimization)
  - 桥接技术 (Bridge for Mesh)
  - 自动互联 (Auto Link in Mesh)

待解技术要点

- Low Cost
  - Highly integrated SoC
- Easy Configuration
  - Smart configuration
- Low Power
  - Good power saving scheme
- Mesh Network
  - Simple solution with Wi-Fi bridge
  - Mesh becomes more important in order to increase the range

提纲

- IOT智能设备的连接技术及其发展趋势
  - Wi-Fi
  - Bluetooth Smart
  - Z-Wave
  - ZigBee
  - Thread
- **IOT设备的 Wi-Fi SoC 智能技术方案**
  - **集成方案** (Highly Integrated SoC)
  - 智能设置 (Smart Configuration)
  - 省电优化 (Power Saving Optimization)
  - 桥接技术 (Bridge for Mesh)
  - 自动互联 (Auto Link in Mesh)

集成方案 (Highly Integrated SoC)

- Integrate components to a single SoC
  - Controller
  - Wi-Fi
  - Low RBOM - integrate as many as possible including PA, LNA, T/R switch etc.
- Process upgrade
  - 55 nm ➔ 40 nm ➔ 28 nm ➔ …
- Other methods that can reduce the die size
  - Reduce memory etc.

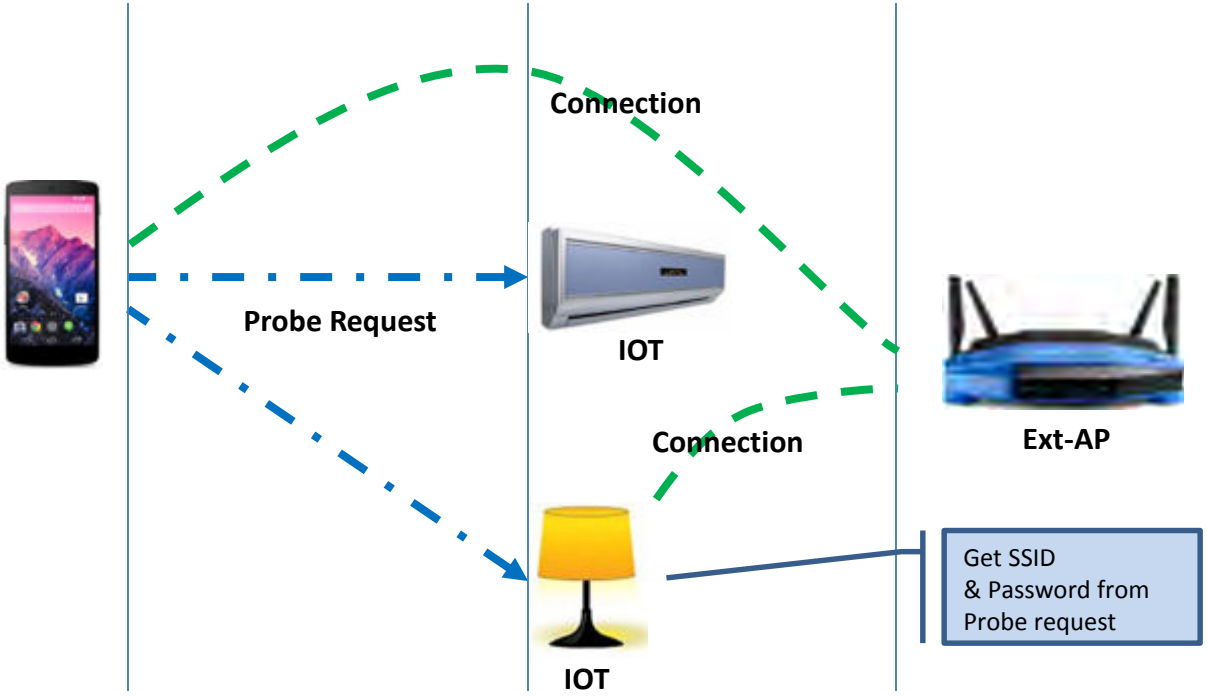
提纲

- IOT智能设备的连接技术及其发展趋势
  - Wi-Fi
  - Bluetooth Smart
  - Z-Wave
  - ZigBee
  - Thread
- **IOT设备的 Wi-Fi SoC 智能技术方案**
  - 集成方案 (Highly Integrated SoC)
  - **智能设置** (Smart Configuration)
  - 省电优化 (Power Saving Optimization)
  - 桥接技术 (Bridge for Mesh)
  - 自动互联 (Auto Link in Mesh)

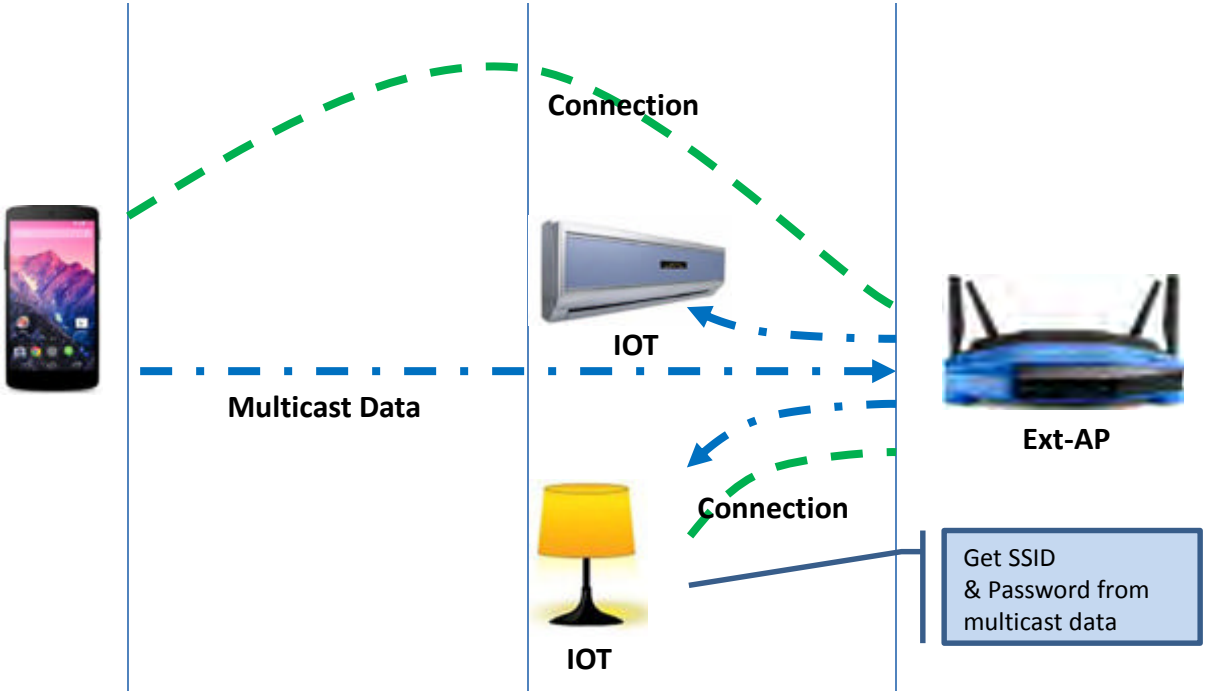
智能设置 (Smart Configuration)

- No screen/No keypad for most of IOT devices
- Configure through Phone/Pad devices
- Solutions
  - Probe Request Based
  - Multicast Data Based
  - Micro AP Based

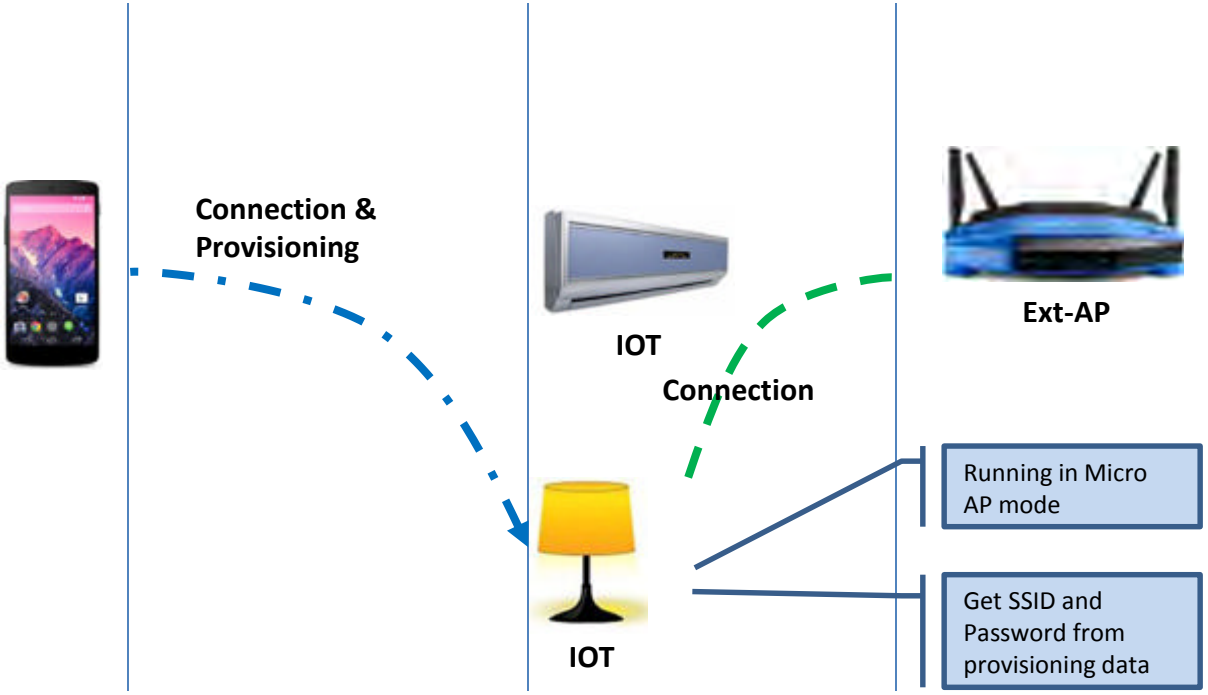
Probe Request Based



Multicast Data Based



Micro AP Based



技术方案比较

	Probe	Multicast	Micro AP
Fast configuration?	✓	✓	✓
Easy to use?	✓	✓	×
Works with all Ext-AP?	✓	×	✓
Android Phone/Pad?	✓	✓	✓
iPhone/iPad (w/o WAC)?	×	✓	✓

- Which one to use?
  - Combined solution
  - Probe Request → Multicast Data → Micro AP

提纲

- IOT智能设备的连接技术及其发展趋势
  - Wi-Fi
  - Bluetooth Smart
  - Z-Wave
  - ZigBee
  - Thread
- **IOT设备的 Wi-Fi SoC 智能技术方案**
  - 集成方案 (Highly Integrated SoC)
  - 智能设置 (Smart Configuration)
  - **省电优化** (Power Saving Optimization)
  - 桥接技术 (Bridge for Mesh)
  - 自动互联 (Auto Link in Mesh)

省电优化 (Power Saving Optimization)

- Reduce transmission power
  - Range is shortened
  - Compensated by mesh topology
- Host controller sleep
  - Offload connection maintenance to Wi-Fi module
  - Keep controller sleep during idle
  - Turn off Wi-Fi module during idle and fast recovery when needed
- Adjustable wakeup period in Wi-Fi
  - Use multiple DTIM scheme
  - Wake up every N beacon intervals

提纲

- IOT智能设备的连接技术及其发展趋势
  - Wi-Fi
  - Bluetooth Smart
  - Z-Wave
  - ZigBee
  - Thread
- **IOT设备的 Wi-Fi SoC 智能技术方案**
  - 集成方案 (Highly Integrated SoC)
  - 智能设置 (Smart Configuration)
  - 省电优化 (Power Saving Optimization)
  - **桥接技术** (Bridge for Mesh)
  - 自动互联 (Auto Link in Mesh)

桥接技术 (Bridge for Mesh)

- Wi-Fi Mesh Network
- What kind of Mesh
- Bridge for Wi-Fi
- Learning Table in Bridge
- Stackable Bridge
- Bridge based Wi-Fi Mesh Network

Wi-Fi Mesh Network

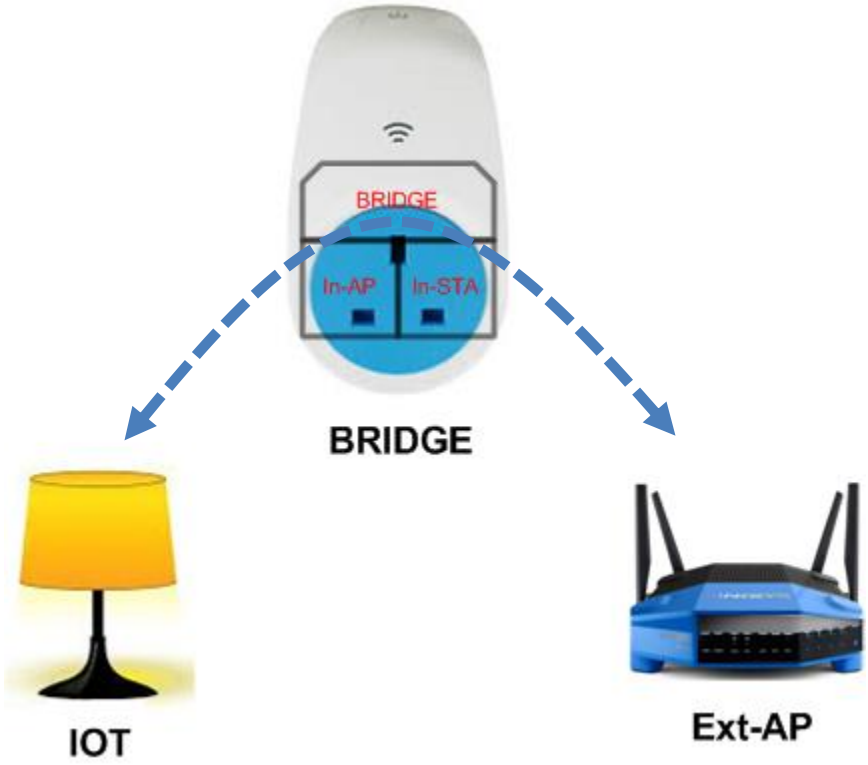
- What is Wi-Fi Mesh?
  - Each node can relay/forward data for the network
  - Router/Portal connected to LAN or Internet
  - Self forming for the best path
  - Self healing to recover the link
- Why Mesh for Wi-Fi network?
  - Compensate the range reduced by lowering transmission power
  - Increase the reliability of network connectivity
- 802.11S (Mesh Specification)
  - Initiated in 2004, ratified in 2011
  - Based on HWMP (Hybrid Wireless Mesh Protocol) for MAC address based routing
  - Used in OLPC (One Laptop Per Child)

What Kind of Mesh?

- Not 802.11S
  - Complicated in implementation
  - Need more resource in memory, CPU power etc. in order to work efficiently
  - Inter-operability issue due to lack of full support from vendors
- Bridge Based Mesh
  - Mature technology
  - Cost-effective
  - Simplified implementation to cover forming and healing

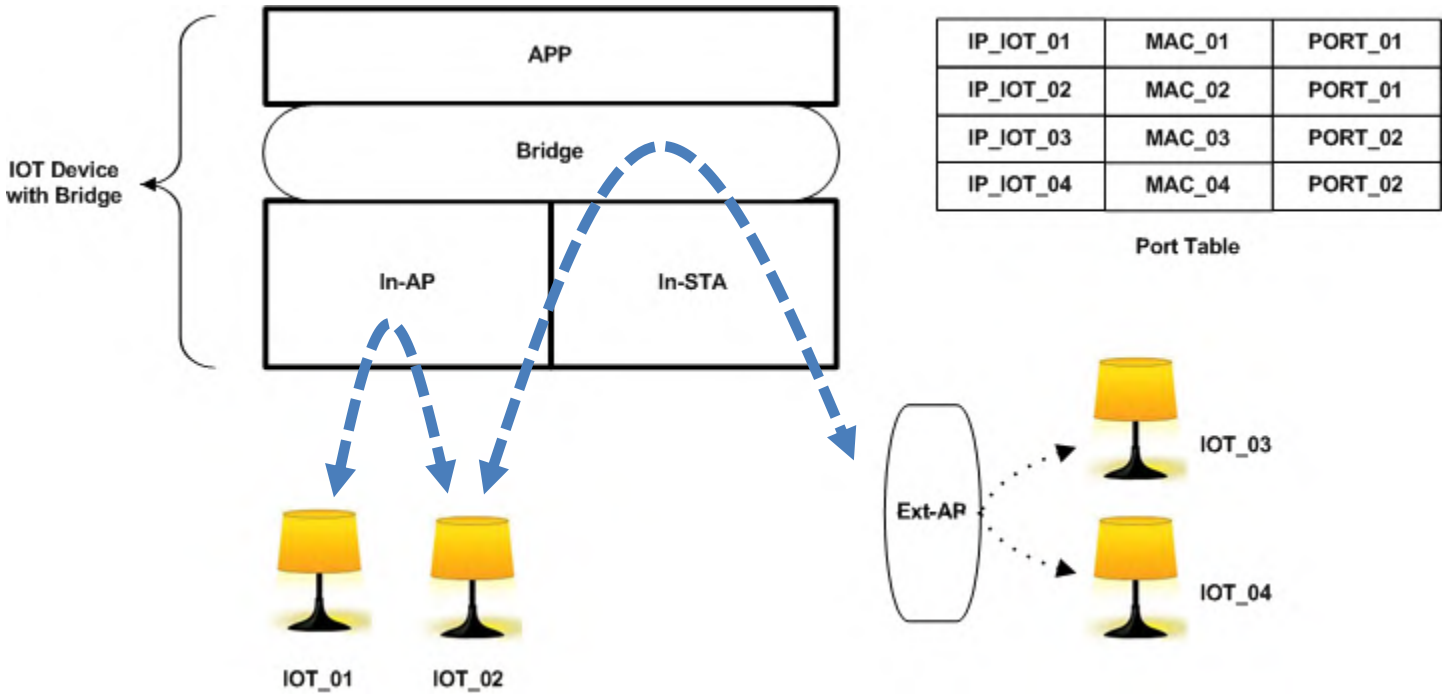
Bridge for Wi-Fi

- Each Bridge has 3 components
  - Bridge
  - In-AP
  - In-STA
- IP/MAC address based
  - Source learning
  - MAC address conversion
  - Broadcast/multicast handling
- Support both IPv4 and IPv6
  - ARP (Address Resolution Protocol) checking for IPv4
  - NDP (Neighbor Discovery Protocol) checking for IPv6
  - DHCP checking
- Packet is forwarded/bridged between IOT device and router



Learning Table in Bridge

- Learning table is built up based on both IP address and MAC address
- Corresponding port number decides where to forward the packet

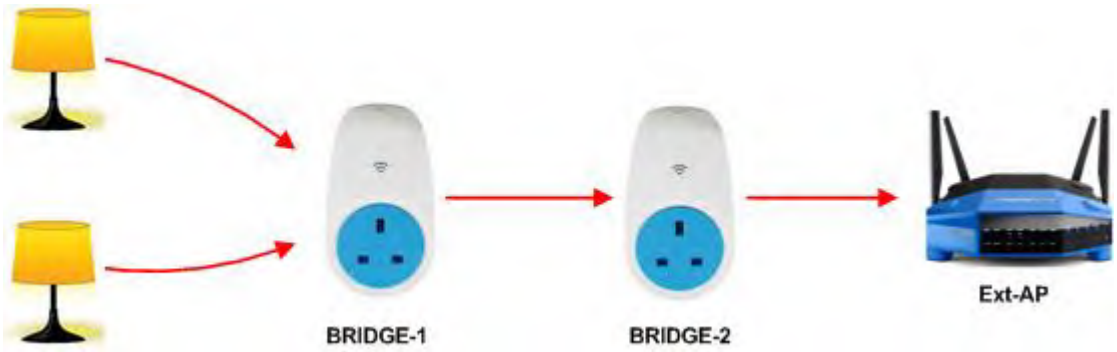


IP_IOT_01	MAC_01	PORT_01
IP_IOT_02	MAC_02	PORT_01
IP_IOT_03	MAC_03	PORT_02
IP_IOT_04	MAC_04	PORT_02

Port Table

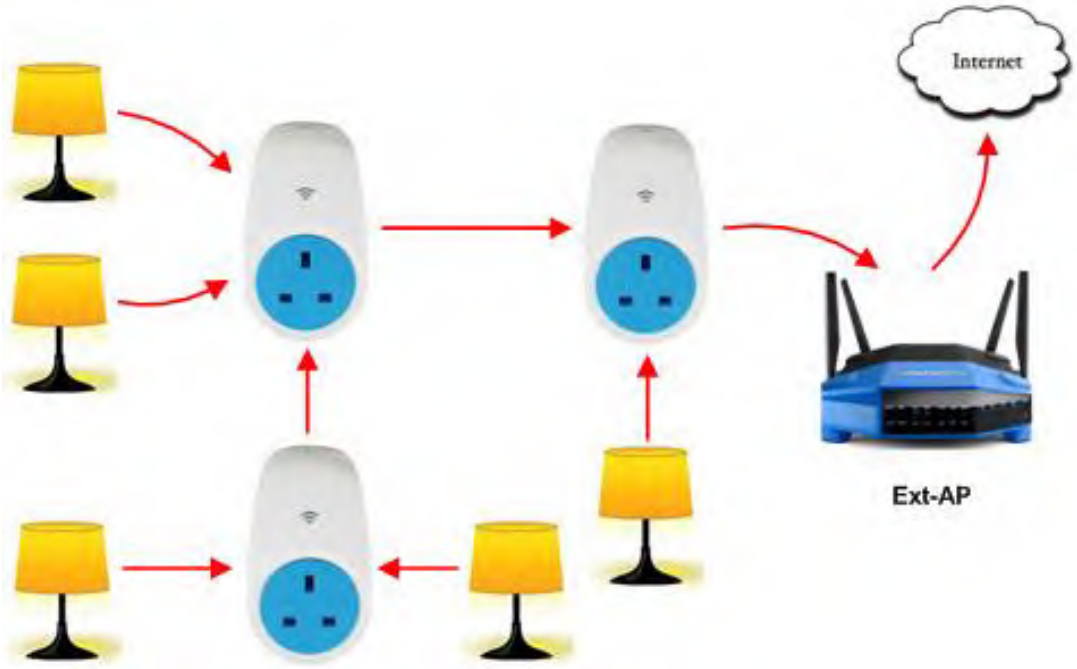
叠桥技术(Stackable Bridge)

- Bridges can be linked to another bridge in order to extend longer range.



Bridge based Wi-Fi Mesh Network

- Multiple bridges linked to each other to forward traffic between IOT devices and router (Ext-AP)



提纲

- IOT智能设备的连接技术及其发展趋势
  - Wi-Fi
  - Bluetooth Smart
  - Z-Wave
  - ZigBee
  - Thread
- **IOT设备的 Wi-Fi SoC 智能技术方案**
  - 集成方案 (Highly Integrated SoC)
  - 智能设置 (Smart Configuration)
  - 省电优化 (Power Saving Optimization)
  - 桥接技术 (Bridge for Mesh)
  - **自动互联** (Auto Link in Mesh)

自动互联 (Auto Link)

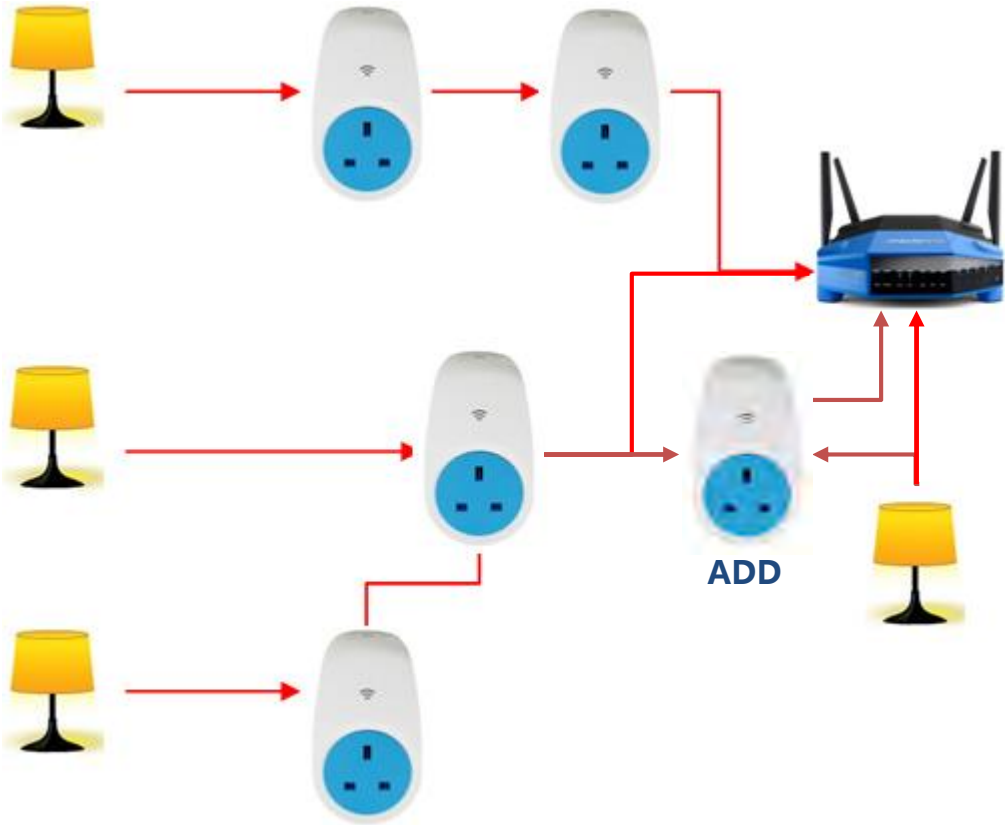
- Link and Path build Up
- Node Addition
- Node Removal
- Link and Path Optimization

创建接点连接(Link and Path build up)

- Forming
  - Simplify the implementation
    - No 802.11aq (shortest path bridge)
    - No 802.1d (spanning tree)
  - Based on Received Signal Strength Indicator (RSSI)
- Healing
  - Dead loop detection
  - RSSI monitoring
    - No change required for good link
    - Periodically scanning to look for better link
      - Node addition/Node removal
  - Auto recovery after link lost

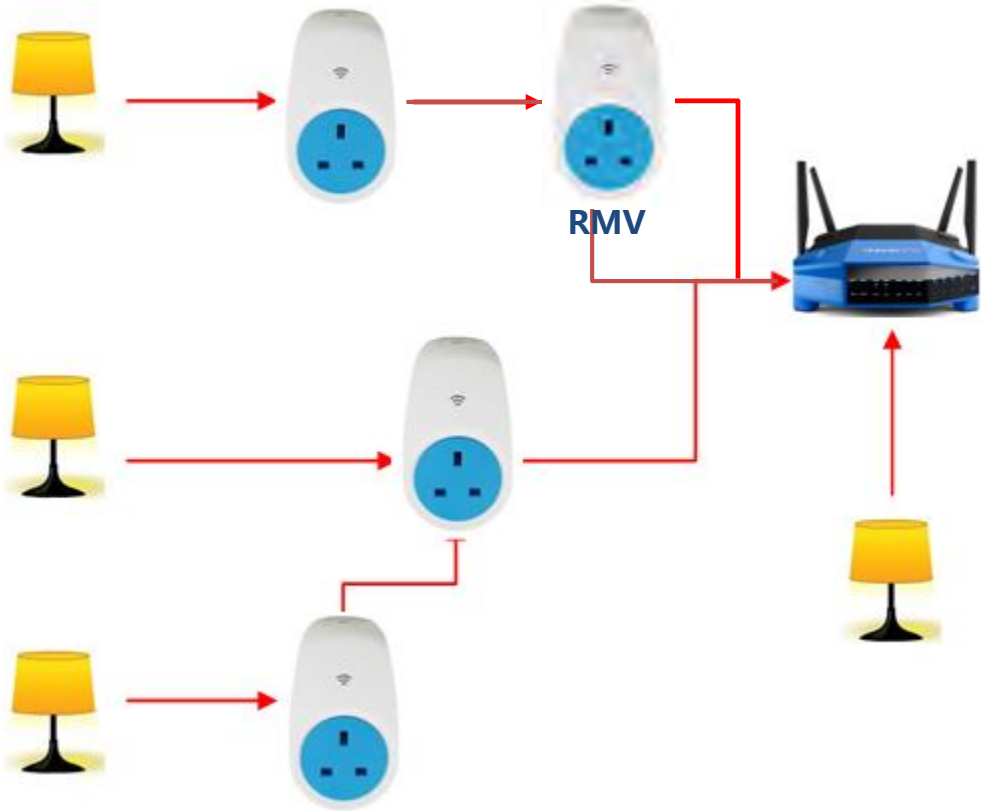
添加接点及续连(Node Addition)

- Link re-established when a new node is added



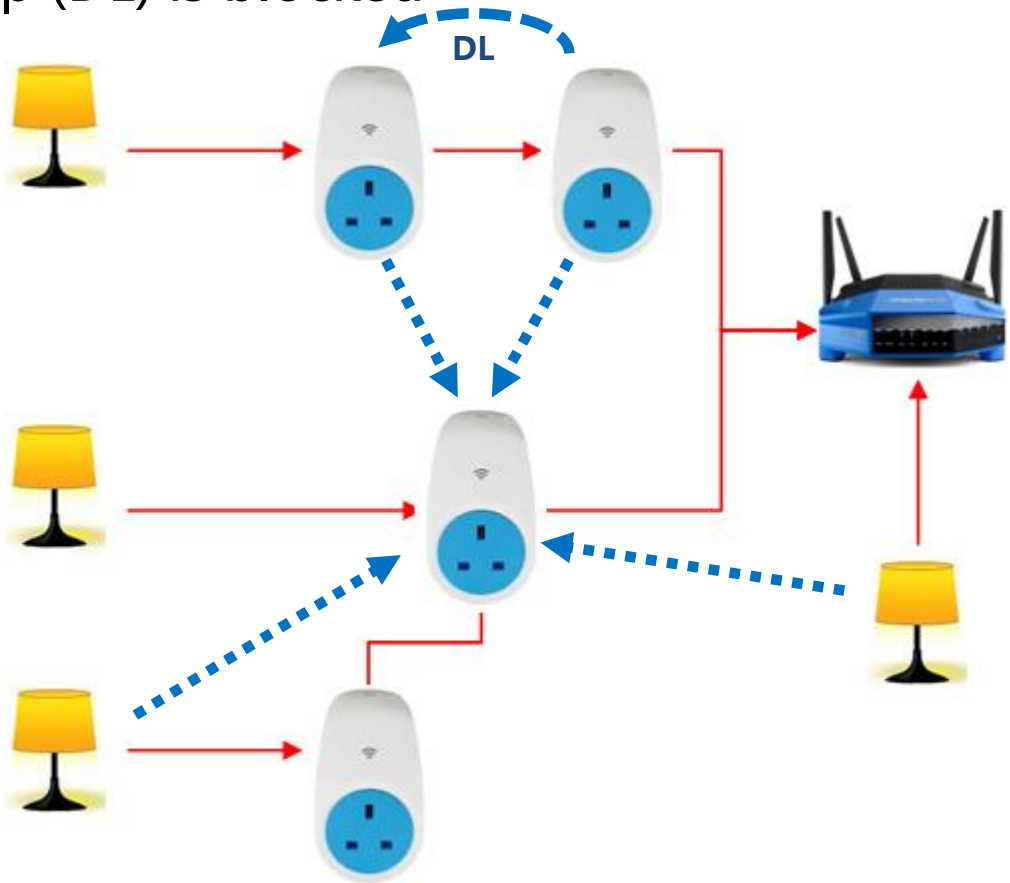
移除接点及续连(Node Removal)

- Link re-established when a node is removed



优化接点连接路径(Link/Path Optimization)

- Redundant links are removed during optimization
- Dead loop (DL) is blocked



Review

前述要点回顾

- Wi-Fi is still a GREAT solution for IOT connectivity
  - Valuable to invest more
- Smart Configuration
  - Provide easy Wi-Fi setup
- Power Optimization
  - Lower transmission power
  - Sleep as long as possible
- Bridge Based Wi-Fi Mesh network
  - Compensate range reduced by lowering transmission power
  - Reduce development cycle and cost with mature technology
  - Optimize link/path to have efficient performance

Thanks!