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Wi-Fi SoC 芯片在IoT智能设备中的应用

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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)

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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?	✓	✓	✗*	✓	✗
High Throughput?	✓	✗	✗	✗	✗
Long Range?	✓	✓*	✗	✗	✗
Internet Connection?	✓	✗	✗	✓*	✓
Power Friendly?	✗*	✓	✓	✓	✓
Good Roadmap?	✓	✓	✗	✓	✓

Wi-Fi is still a GREAT solution for IOT

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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

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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.

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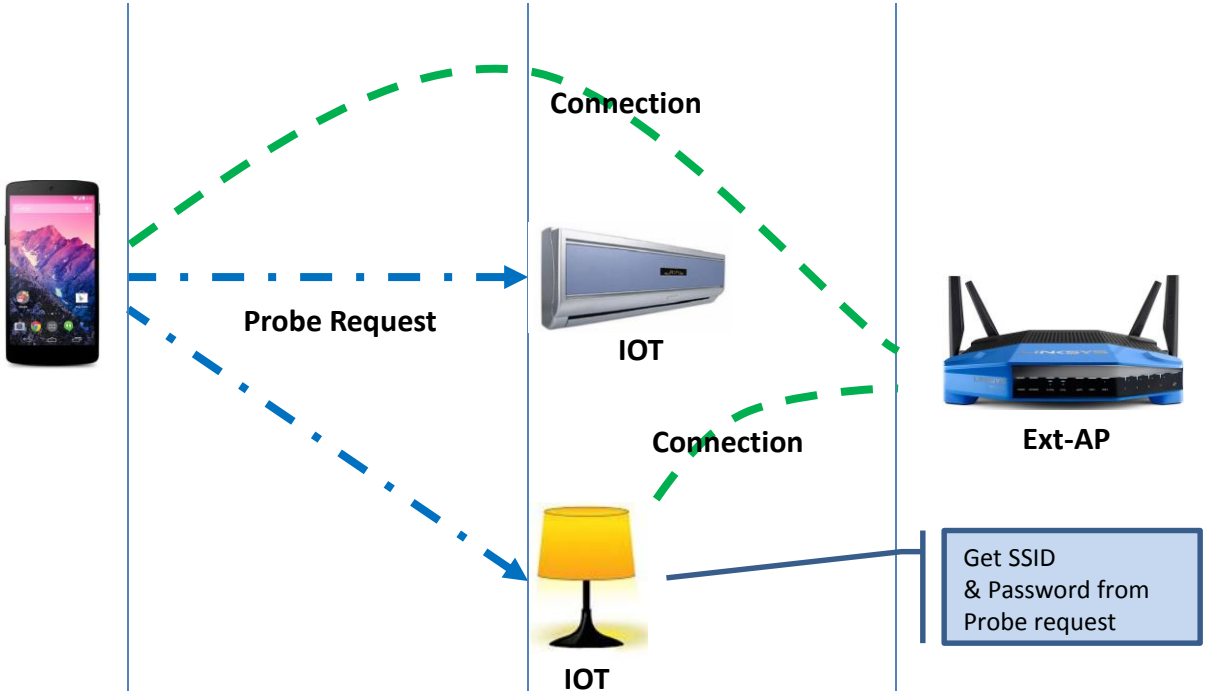
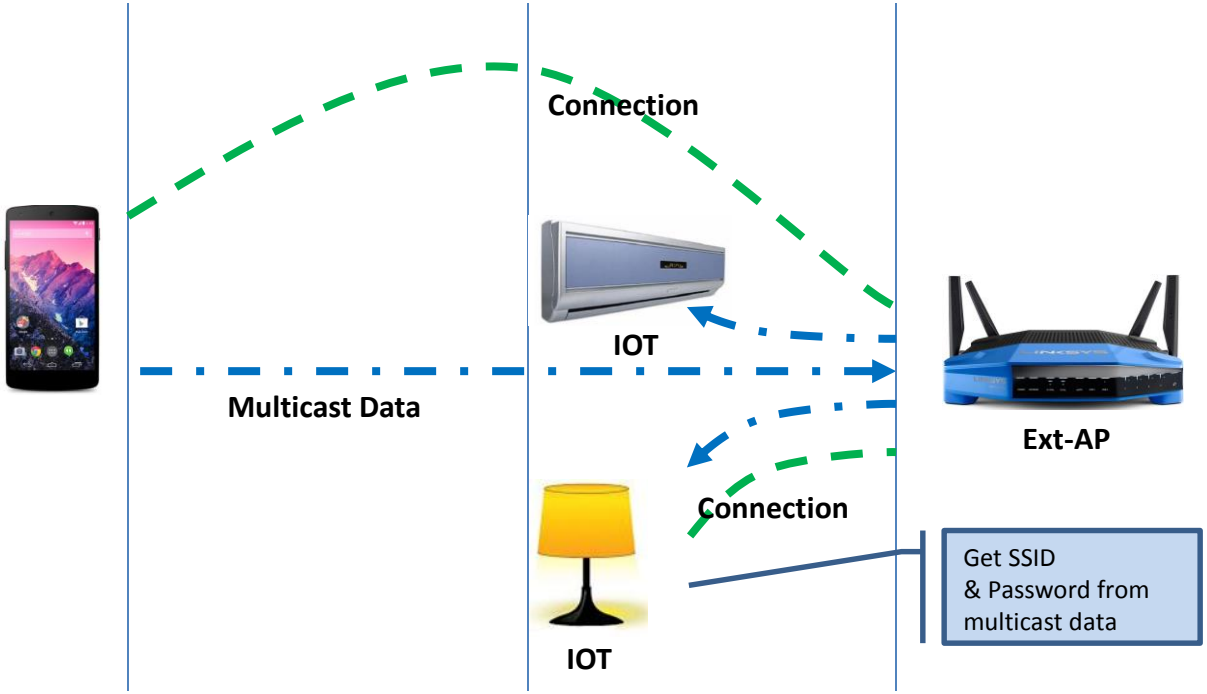
智能设置 (Smart Configuration)

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

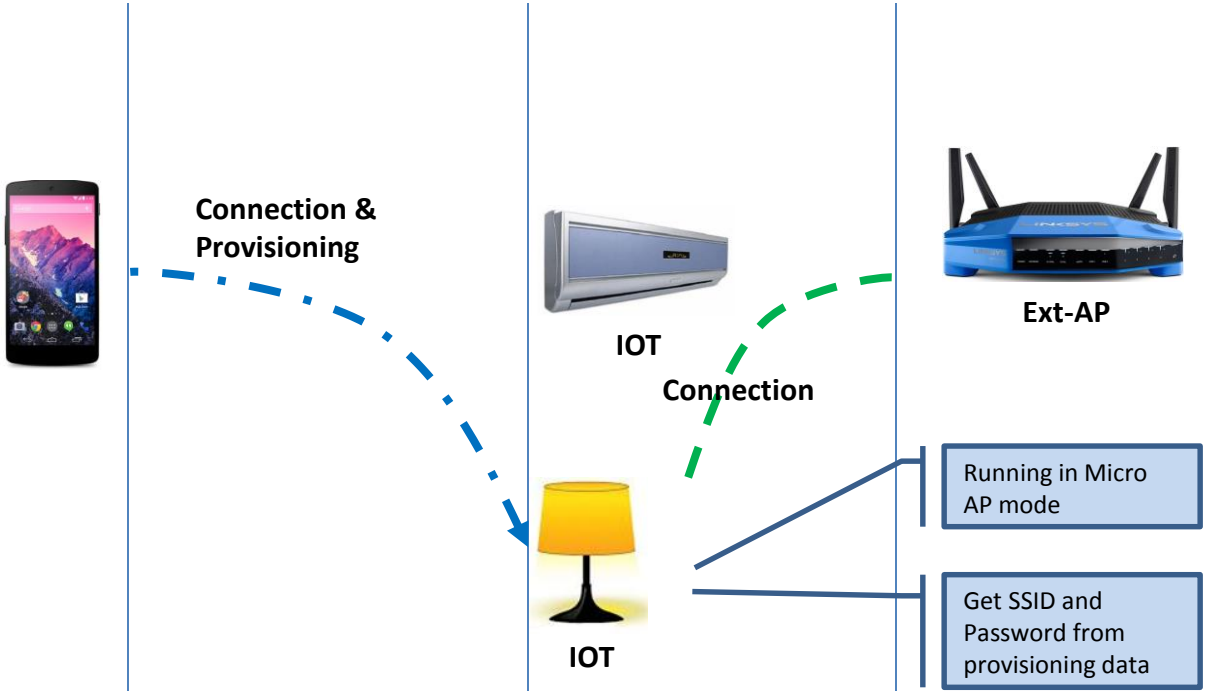
Probe Request Based



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

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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

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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

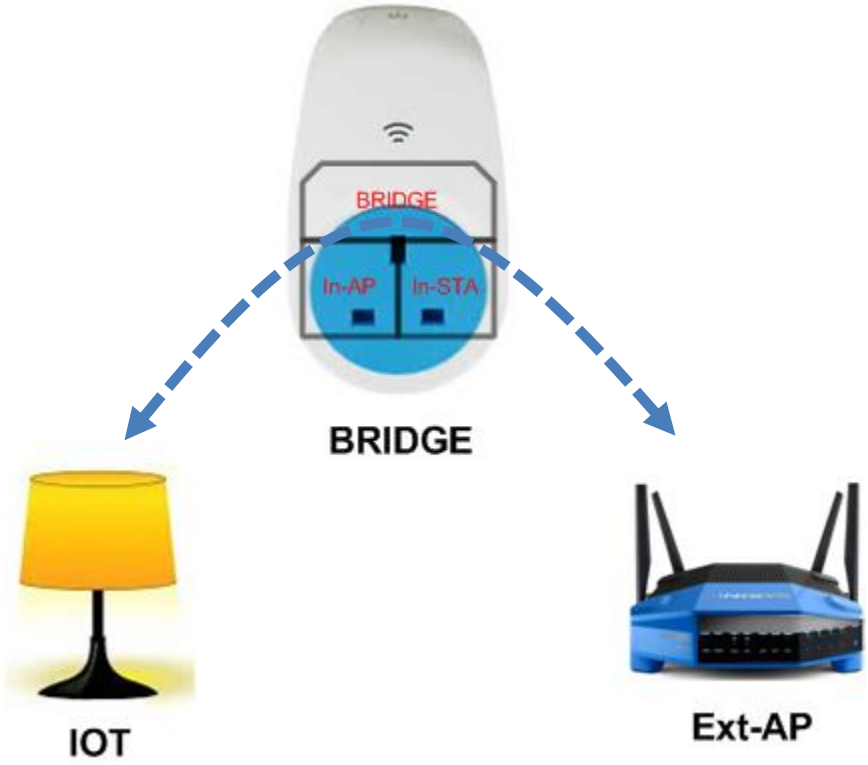
- What is Wi-Fi Mesh?
  - Each node can relay/forward data for the network
  - Router/Portal connected to LAN or Internet
  - Self forming for the best path
  - Self healing to recover the link
- Why Mesh for Wi-Fi network?
  - Compensate the range reduced by lowering transmission power
  - Increase 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

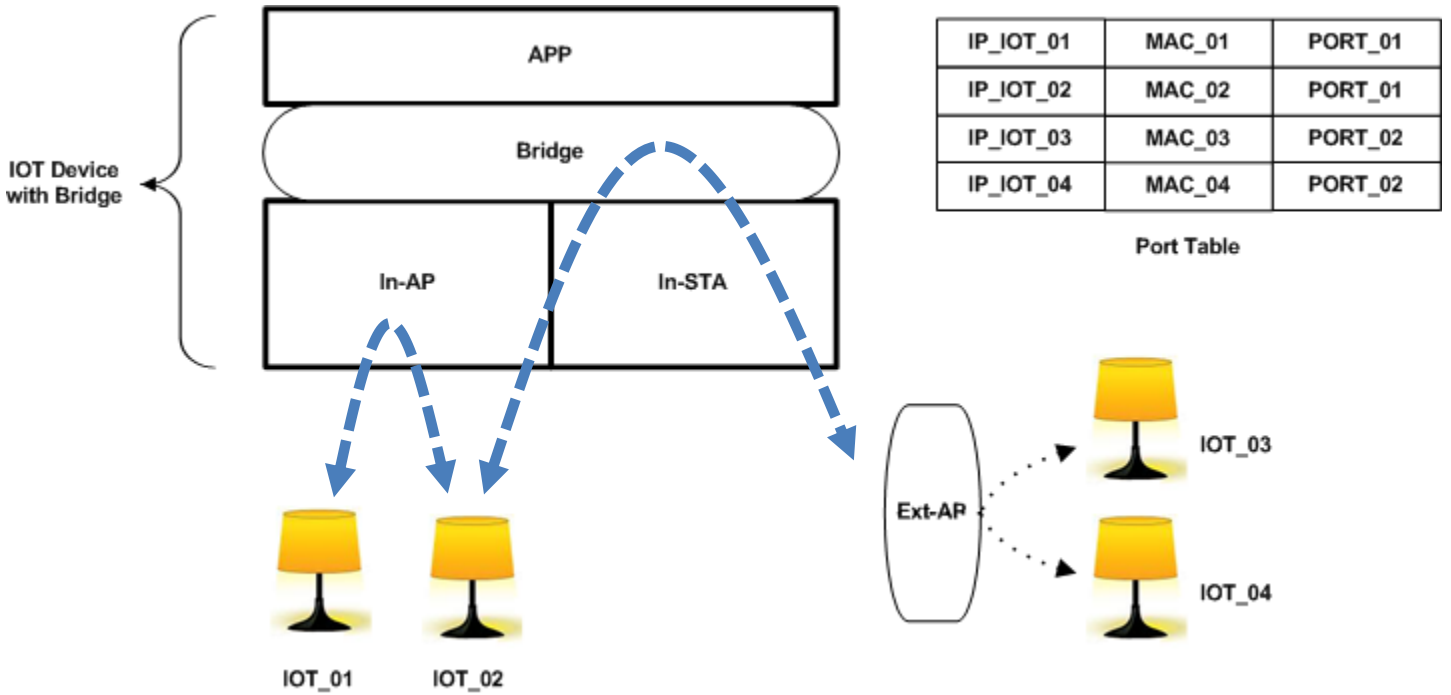
Bridge for Wi-Fi

- 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

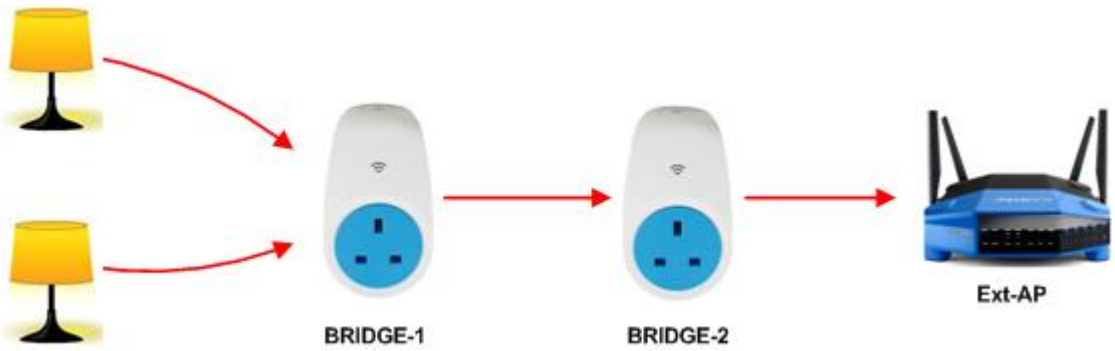


IP_IOT_01	MAC_01	PORT_01
IP_IOT_02	MAC_02	PORT_01
IP_IOT_03	MAC_03	PORT_02
IP_IOT_04	MAC_04	PORT_02

Port Table

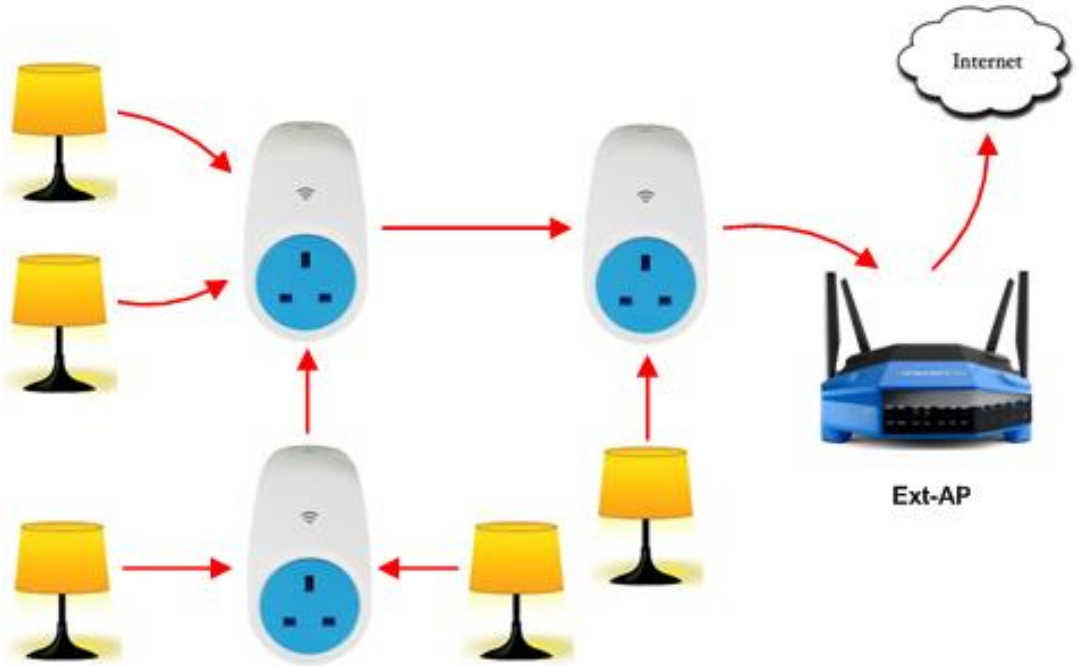
叠桥技术(Stackable Bridge)

- 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)



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自动互联 (Auto Link)

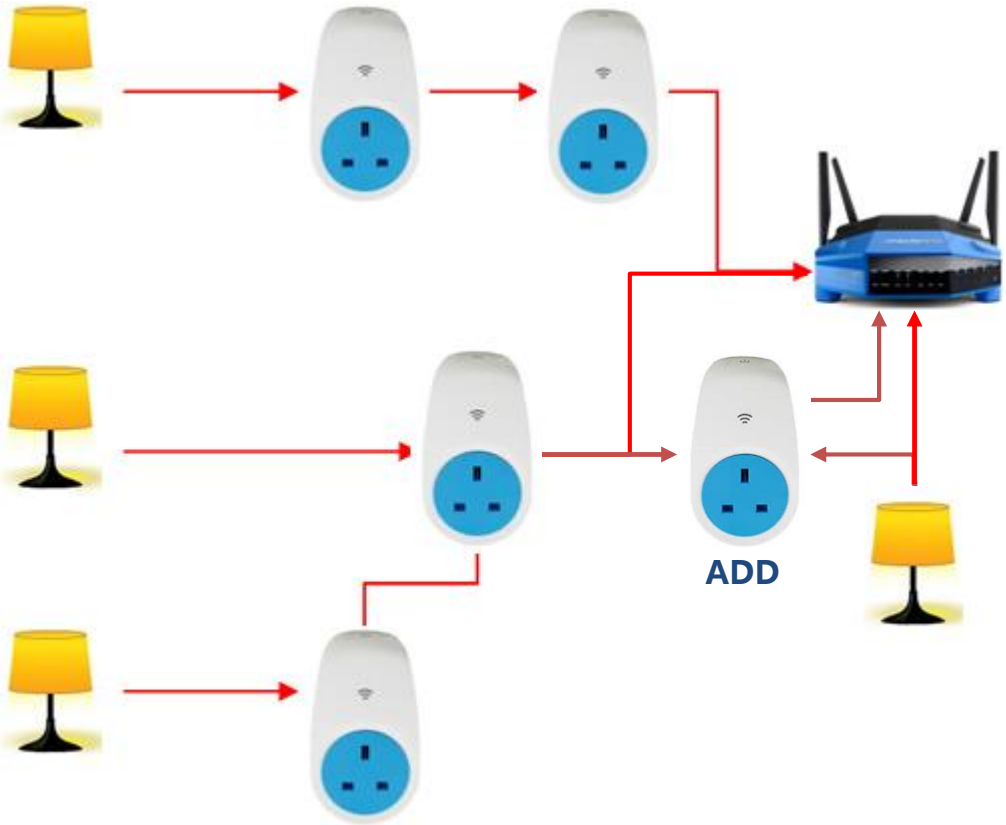
- Link and Path build Up
- Node Addition
- Node Removal
- Link and Path Optimization

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

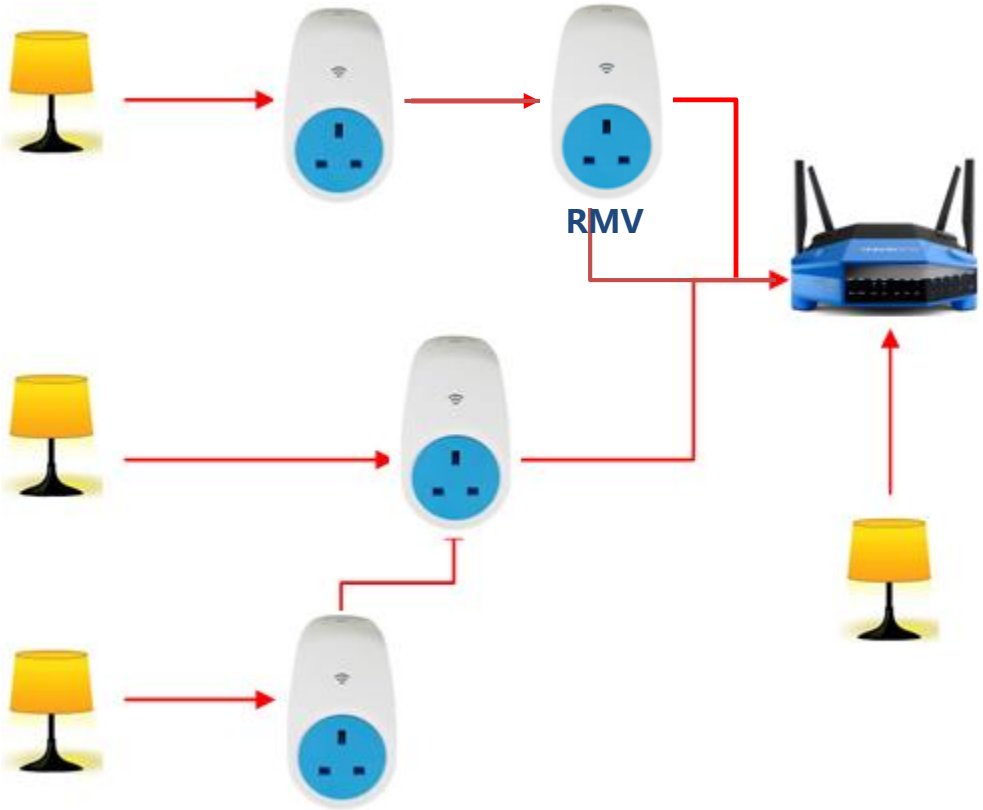
添加接点及续连(Node Addition)

- Link re-established when a new node is added



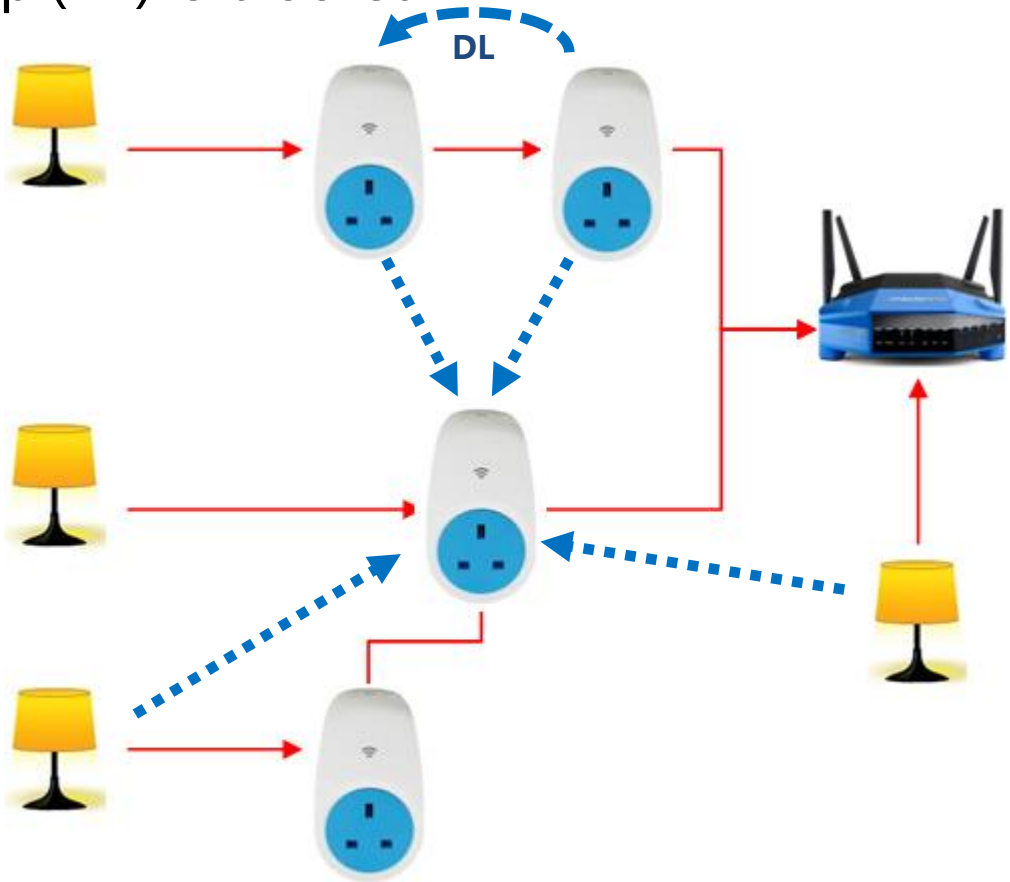
移除接点及续连(Node Removal)

- 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!