WLAN SFN Technology White Paper

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Abstract:

The same-frequency network (SFN) is an innovative solution designed based on Huawei's agile distributed Wi-Fi architecture to solve roaming issues in the healthcare system. This document describes the SFN roaming and its implementation.

Acronyms and Abbreviations

Acronym/Abbreviation	Full Name
AP	Access point
AC	Access controller
RU	Remote unit
SFN	Same-frequency network

Contents

Figures

1 Background

In recent years, wireless healthcare has become the most concerned ICT technology and means in the healthcare industry. Most tertiary hospitals have established complete healthcare information systems such as the Health Information Systems (HIS) and picture archiving and communication system (PACS). Medical personnel can access, modify, and input patients' information, diagnosis reports, and treatment solutions through wired networks. Because information points are fixed on wired networks, limitations exist in healthcare information systems. Therefore, wireless healthcare carried by Wi-Fi is developing rapidly.

Due to inherent characteristics of the healthcare ecosystem, such as poor robustness of the application software system and outdated wireless terminals, the ecosystem has strict requirements on the roaming performance of Wi-Fi networks. Hospitals want a Wi-Fi network with roaming performance that can shield terminal differences, minimize packet loss, and even lose no packets. Such a Wi-Fi network ensures service continuity during the ward-round of medical personnel using handheld terminals (involving the infusion check, medicine check, infusion inspection, and vital sign recording).

Based on the agile distributed Wi-Fi architecture, Huawei launches the same-frequency network (SFN) roaming solution. In this architecture, different RUs use the same channel for networking, and a central AP can implement collaboration among different RUs to control which RU is used to receive and send data. Compared with traditional STA-triggered proactive roaming solutions, this solution has obvious advantages such as no awareness to roaming STAs and little packet loss during handovers. Therefore, the SFN roaming solution is applicable to healthcare and other scenarios that have high requirements on smooth mobile roaming.

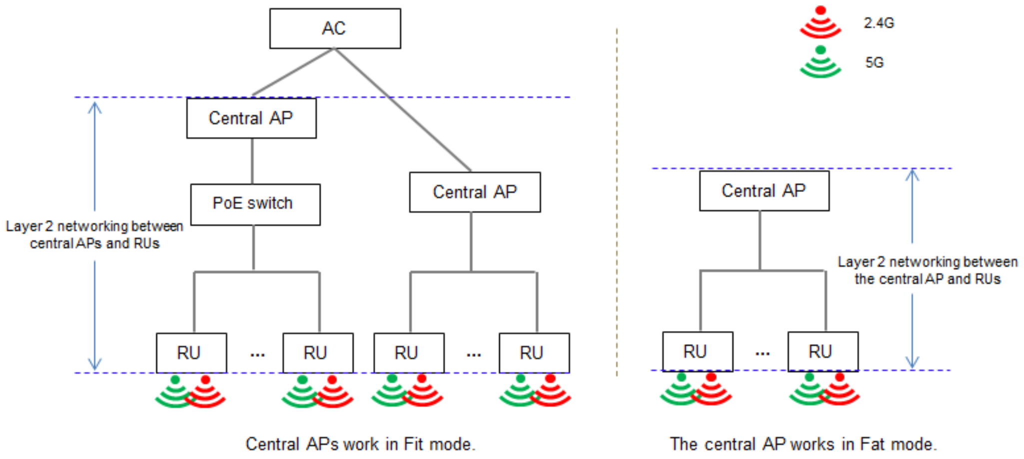
This document describes the implementation of Huawei SFN technology and its typical applications. For details about the agile distributed Wi-Fi architecture, see the *Agile Distributed Wi-Fi Technology White Paper*.

2 Implementation

Traditional roaming technologies allow different APs to work independently and transmit WLAN signals of different basic service set identifiers (BSSIDs) (similar to MAC addresses of wired devices). That is, STAs know clearly which WLAN signals are provided by which APs. Similarly, to send radio signals, the STAs need to specify the destination BSSID so as to send the signals to the correct APs. When a STA roams between APs, the STA triggers a roaming process to dynamically switch from one AP to another.

During the movement of a STA, though the AP that receives and transmits signals changes, the STA does not perceive roaming if the BSSID remains unchanged. The reassociation, reauthentication, and key re-negotiation in the traditional roaming handover are not performed. In this manner, data forwarding is not interrupted and few packets are lost during the roaming handover.

Figure 2-1 Typical networking of the agile distributed Wi-Fi solution



Based on the agile distributed Wi-Fi architecture, a central AP can implement collaboration among different RUs to control which RU is used to receive and send data. For each STA, all RUs associated with a central AP have the same channel and BSSID. After STAs connect to RUs, the channel and BSSID remain unchanged within the range of the central AP associated with the RUs. Therefore, the STAs do not perceive roaming.

In the SFN roaming solution, STA roaming is achieved through the following phases: access control, roaming decision, and handover control. This chapter describes the principles of the SFN roaming solution in these phases.

2.1 Access Control

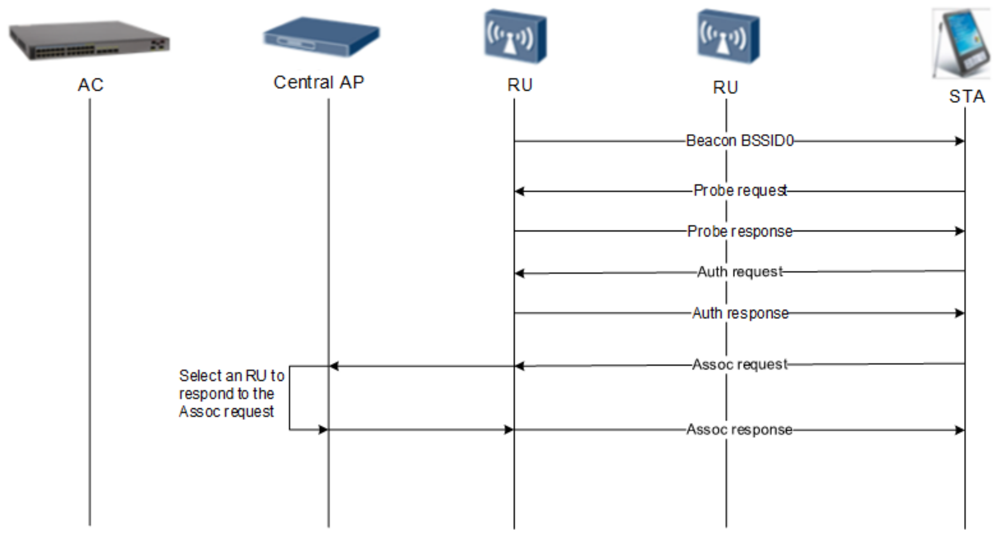
In the agile distributed Wi-Fi architecture, central APs can work in Fit or Fat AP mode. Both modes support SFN roaming. This section describes the SFN roaming using the widely applied Fit mode of central APs. Assume that RUs work on channel 1 and a 2.4 GHz STA accesses the SFN.

According to the SFN feature in the agile distributed architecture, all RUs use the same BSSID to transmit signals. The STA access process on the SFN is similar to the common access process. The differences are as follows in the association phase:

1. A STA sends a Probe Request frame on channel 1. In this case, multiple RUs receive the Probe Request frame from the STA.
2. All the RUs that receive the Probe Request frame respond with a Probe Response frame using the public BSSID.
3. The STA sends an Auth Request frame. All the RUs that receive the Auth Request frame respond with an Auth Response frame using the public BSSID.
4. The STA sends an Assoc Request frame. All the RUs receive the Assoc Request frame and send it to the central AP for processing. The central AP selects the RU that reports the highest RSSI to respond to the STA with an Assoc Response frame. Subsequently, only the selected RU communicates with the STA.

Subsequently, the key negotiation and data forwarding phases are performed, which are the same as those in the traditional roaming, and not mentioned here.

Figure 2-2 STA access control

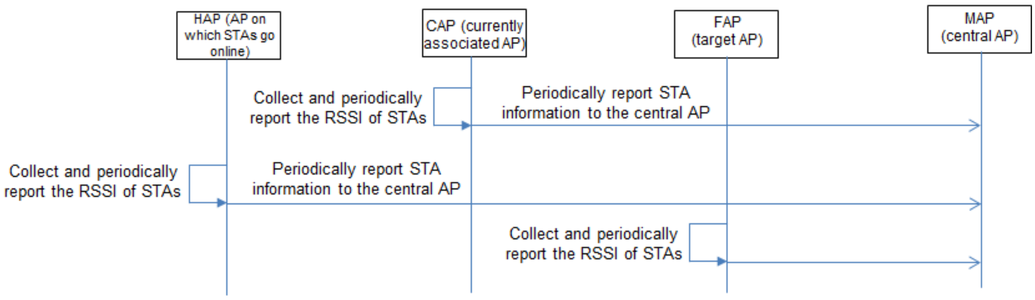


2.2 Roaming Decision

After a STA accesses RUs, each RU connected to the same central AP continuously collects the STA RSSI and periodically reports the RSSI to the central AP for decision making. RUs collect STA RSSI information from data, management, and control packets sent by the STA.

In each reporting period, the RSSI values in the received data, management, and control packets are averaged.

Figure 2-3 Process of RUs collecting the STA RSSI



When the STA moves, the central AP determines roaming based on the RSSI reported by the RUs. The roaming decision is triggered by events. That is, each time an RU reports the RSSI of the associated STA, the central AP performs a handover decision process. The decision process is mainly a process of comparing the RSSI. The central AP makes a roaming decision based on the STA RSSI collected and reported by the serving AP and each target AP. When either of the following conditions is met, a roaming handover is triggered:

- STA RSSI reported by a candidate target RU – STA RSSI reported by the serving RU ≥ Relative threshold for a roaming handover
- Number of consecutive times the RSSI reported by a candidate target RU is higher than that reported by the serving RU > Absolute number of roaming handovers

The handover is prohibited if the time for associating with RUs is shorter than the association holding time, preventing ping-pong handovers.

2.3 Handover Control

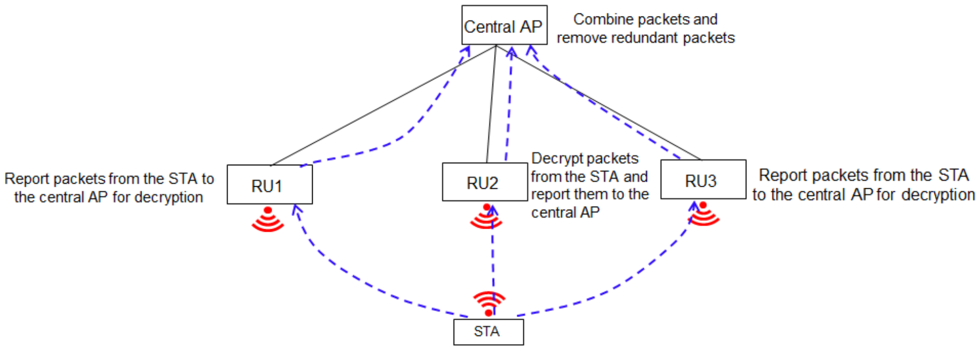
In the SFN roaming solution, roaming decision and control are not performed on the STA side. When the STA moves, the central AP continuously makes roaming decisions. When the roaming conditions are met, the central AP migrates the STA's context packets. That is, the context packets are migrated from the current RU to the target RU, and the target RU sends and receives user packets. To prevent packet loss during handovers, both uplink and downlink packets are specially processed in the SFN roaming solution. This is also a key to achieving little packet loss in the SFN roaming solution. The following describes how uplink and downlink packets are processed in the SFN roaming solution.

1. Uplink RU diversity

   For uplink packets, to reduce the data packet loss rate during roaming, multiple RUs receive the packets at the same time. The RUs then send the received packets to the central AP. The central AP decrypts and combines the packets, and removes redundant packets.

   As shown in Figure 2-4, all RUs use the same BSSID, so the STA's data packets can be received by RU1, RU2, and RU3 at the same time. Currently, the STA key exists only on the associated RU2. In most cases, RU1 and RU3 discard STA packets. To reduce packet loss during roaming, the RUs send 802.11 packets from the STA to the central AP for decryption and combination. The central AP also removes redundant packets. This process can be considered as a macro diversity process and is also widely used in a cellular system. Macro diversity can obtain the diversity gain of uplinks, reducing packet loss.

Figure 2-4 RU uplink diversity process

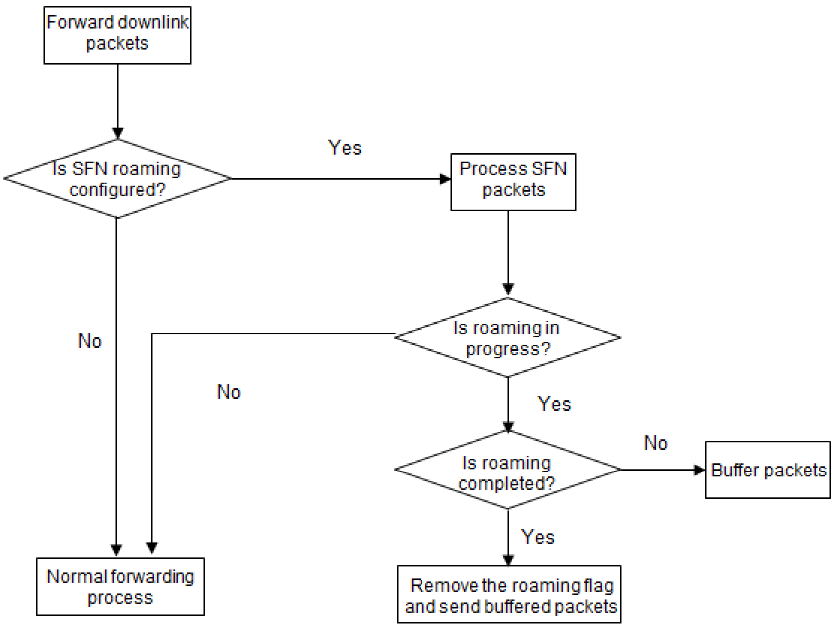


2. Downlink packet buffering

   During the roaming process, downlink packets are sent to the current RU associated with the STA. After the roaming is complete, network entries are updated and downlink packets are sent to the new RU. During this process, if the original RU cannot send the remaining packets through the radio link between the original RU and the STA, the downlink packets are lost. In the SFN roaming solution, the central AP buffers the packets to prevent packet loss.

   When detecting that a STA is to roam, the central AP identifies the STA as a roaming STA. At this time, the central AP buffers downlink packets sent to the RU associated with the STA, deletes the forwarding entry, and does not send packets to the current RU. After roaming is complete, the central AP sends the buffered packets to the target RU through a new forwarding entry. Figure 2-5 shows the downlink packet buffering process.

Figure 2-5 Process of buffering downlink packets on the central AP



3 Customer Benefits

1. No specific requirements on STAs

   In traditional roaming scenarios, roaming is triggered by STAs. Roaming performance is directly affected by STAs' own capabilities, such as support for 802.11k, 802.11v, and 802.11r, and roaming sensitivity. SFN roaming based on the agile distributed architecture is controlled by the network and has no specific requirements on STAs. In healthcare systems with many outdated terminals, SFN roaming technology minimizes the requirements on STAs and shields the impact of STA differences on the roaming effect.

2. Superb roaming performance

   Based on the agile distributed Wi-Fi architecture, different RUs work on the same channel for networking, and a central AP can implement collaboration among different RUs to control which RU is used to receive and send data. When a STA moves on an agile distributed SFN, the STA is unaware of roaming, just like associated with an AP with unlimited coverage. During the entire movement process, the packet loss rate is no higher than 0.5% and the delay is no longer than 50 ms, which are of great importance in the healthcare sector.

3. Simplified installation and O&M

   In the agile distributed architecture, RUs can be easily deployed in each room to provide pervasive coverage as well as excellent roaming experience. Compared with competitors' solutions such as remote antenna deployment, this mode features easier installation, higher performance, fewer managed nodes, and fewer licenses.

4 Typical Application

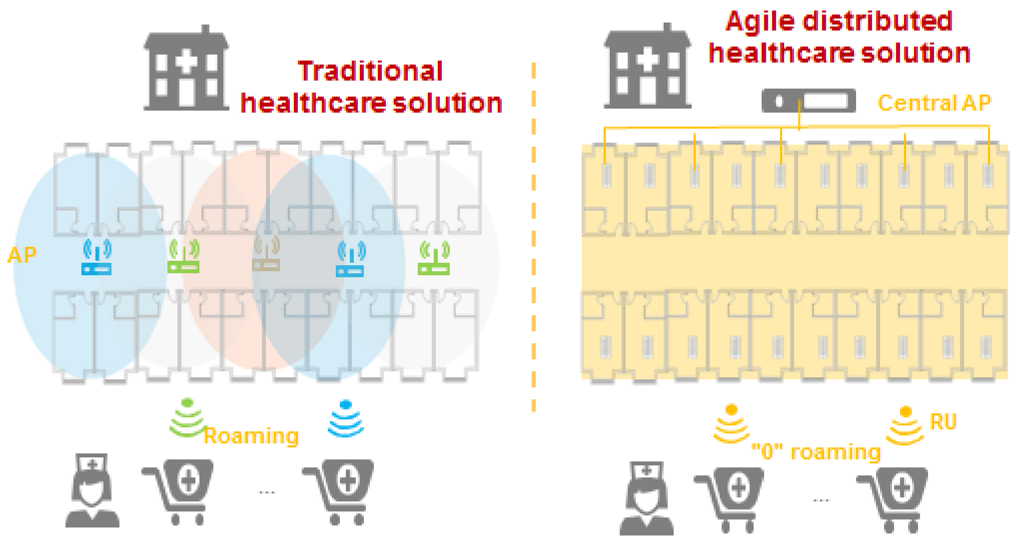
Compared with traditional STA-triggered proactive roaming technology, SFN roaming based on the agile distributed architecture has obvious advantages such as fast roaming, no awareness to roaming STAs, and little packet loss during handovers. Therefore, SFN roaming is applicable to scenarios that have high requirements on smooth mobile roaming. Pay attention to the following constraints when using SFN roaming:

1. The SFN feature supports only encrypted networks, such as networks encrypted using PSK, 802.1x, or Portal+PSK.
2. The SFN feature does not support inter-central AP roaming. If roaming between central APs is required, perform the common roaming process.
3. After the SFN feature is enabled, a maximum of 128 SFN STAs and a maximum of 128 STAs on other VAPs are supported on a single frequency band (2.4 GHz or 5 GHz) within the scope of a central AP.
4. After the SFN feature is enabled, all RUs must be configured to work on the same channel.
5. During the 5G SFN deployment, configure non-radar channels.
6. The SFN feature is mutually exclusive with the following features:
   - Channel calibration
   - Channel scanning
   - Smart roaming
7. Use the SFN feature under the guidance of Huawei engineers.

4.1 Wireless Healthcare

In recent years, wireless healthcare has become the most concerned ICT technology and means in the healthcare industry. Most tertiary hospitals have established complete healthcare information systems such as the Health Information Systems (HIS) and picture archiving and communication system (PACS). Medical personnel can access, modify, and input patients' information, diagnosis reports, and treatment solutions through wired networks. Because information points are fixed on wired networks, limitations exist in healthcare information systems. Therefore, wireless healthcare carried by Wi-Fi is developing rapidly. Due to the specialty of healthcare applications, Wi-Fi terminals have high requirements for service continuity during mobile roaming. Therefore, smooth roaming is needed to achieve fast handovers and little packet loss. This is a challenge for Wi-Fi in the wireless healthcare application.

Figure 4-1 Application of the agile distributed Wi-Fi architecture in wireless healthcare



Based on the agile distributed Wi-Fi architecture, Huawei launches the SFN roaming solution. A central AP can implement collaboration among different RUs to control which RU is used to receive and send data. Compared with traditional STA-triggered proactive roaming technology, this solution has obvious advantages such as fast roaming, no awareness to roaming STAs, and little packet loss during handovers. The test result shows that Huawei's SFN feature meets the Wi-Fi roaming performance requirement in wireless healthcare scenarios.

4.2 Warehousing and Logistics

In the warehousing and logistics field, there are a large number of metal shelves in a warehouse. In traditional Wi-Fi deployment mode, it is difficult to achieve complete Wi-Fi coverage for the entire warehouse. The following methods can be used to provide pervasive coverage of radio signals:

1. Increase the AP deployment density. This brings two problems:
   - Sharp increase in network deployment costs
   - Frequent handovers of handheld Wi-Fi terminals for scanning goods during the movement, increasing the probability of packet loss and lowering the Wi-Fi network reliability.
2. Deploy a WLAN through remote radio coverage for rooms in indoor distributed mode. This method also causes two problems:
   - The length of radio cables is limited, therefore limiting the deployment area.
   - All RUs are essentially APs, with small system throughput.

Huawei's agile distributed Wi-Fi architecture is applicable to this scenario. This architecture and SFN technology together simplify deployment, reduce costs, and ensure reliability of smooth mobile roaming on the Wi-Fi network.