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WHITE PAPER

ZERO LATENCY ROAMING

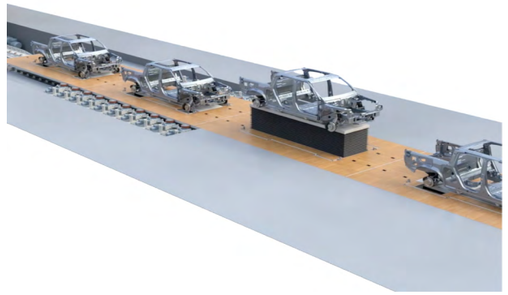
R3 Solutions

A Peppermint Company

R3 Solutions GmbH Kurfürstendamm 194 · 10707 Berlin · Germany · contact@r3.group · www.r3.group

WHY ASSEMBLY LINES NEED ZERO-LATENCY ROAMING

Modern automotive assembly lines increasingly rely on mobile production carriers, often referred to as skillets, to move vehicle bodies, battery packs, or other large assemblies through the manufacturing process. These systems are not passive transport platforms. They often include onboard controllers, lift axes, sensors, actuators, and safety devices, all of which must exchange control and safety data with the surrounding automation system.



Wireless Skillet Assembly Line

In a typical skillet line, each skillet has a unique ID. The line control system knows where the skillet is, often using barcode readers, transponders, or zone sensors. Control data is exchanged with onboard PLCs, while power is provided separately through conductor rails, contact lines or inductive power transfer. Traditionally, the communication path has been implemented using conductor line bus systems, slotted waveguides, or leaky coax infrastructure.

These technologies provide a guided communication medium along the line, but they also introduce mechanical complexity, installation effort, maintenance requirements, and limitations in layout flexibility. As production systems become more modular and adaptable, wireless communication becomes highly attractive.

However, replacing a physical communication path with standard Wi-Fi creates a fundamental challenge: the wireless network must support deterministic control, safety communication, and seamless roaming over long line distances.

SKILLET CONTROL AND COMMUNICATION BASICS

A skillet line is a moving automation system. The line controller must know where each mobile unit is located, what process step it is currently executing, and which commands need to be sent to the onboard controller. Depending on the application, this may include lift commands, positioning data, interlocks, safety status, diagnostic information, and non-critical operational data. The key communication requirements are:

1. Continuous control data exchange The onboard controller must remain connected to the line control system with predictable cycle times.

2. Safety data transmission Safety controllers must exchange safety-related telegrams within defined time limits. If telegrams are delayed or lost beyond the safety protocol watchdogs, the system may enter a fail-safe state.

3. Reliable identification and position-based behavior The system must know when a skillet moves from one communication zone to the next.

4. Seamless transition between coverage areas
Roaming must not interrupt control or safety communication.

5. Coexistence with non-critical traffic
Best-effort data may be present, but it must never compromise safety or control traffic.

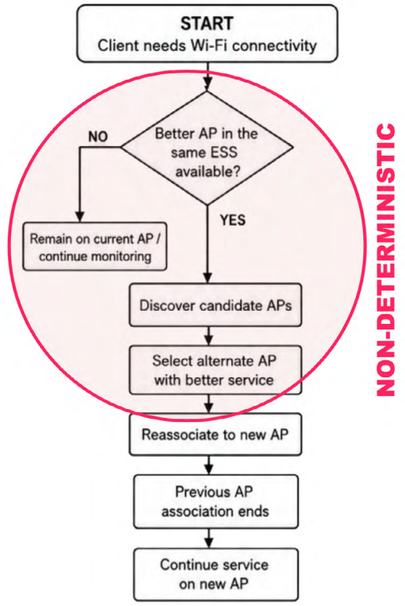
The challenge is not simply to “provide wireless coverage.” The challenge is to provide deterministic wireless behavior while the mobile device is moving through the line.

WHY STANDARD WI-FI IS NOT ENOUGH

Standard Wi-Fi was designed as a flexible, high-throughput communication technology. It is highly successful for office, IT, and general-purpose connectivity. However, conventional Wi-Fi is not deterministic by design. Two limitations are especially relevant for skillet lines:

1. Non-deterministic medium access

In standard Wi-Fi, devices contend for access to the wireless medium. Before transmitting, a device checks whether the channel is free, waits for defined timing intervals, and may defer transmission if another device is active. This mechanism is efficient for general data communication, but it does not provide guaranteed channel access for time-critical industrial traffic. For cyclic control and safety communication, this creates a problem. Even small variations in access delay can accumulate with retransmissions, interference, or increased traffic load. Thus, standard Wi-Fi medium access is inherently non-deterministic.



Simplyfied standard Wi-Fi roaming flowchart

2. Non-deterministic roaming

Roaming is the transition from one subnet or cell to another. In conventional Wi-Fi, roaming decisions are often based on signal strength (see flow-chart in the middle of the page), client behavior, scanning procedures, authentication, reassociation, and vendor-specific mechanisms. Even with fast roaming extensions, the process may still introduce timing uncertainty.

For a moving skillet, this uncertainty is critical. The safety and control protocols continue to run while the radio link is transitioning. Watchdogs and timeouts do not pause simply because a Wi-Fi client is scanning or reassociating. If roaming takes too long, control packets may be delayed and safety packets may time out.

ROAMING AS A CRITICAL TRANSITION

Roaming is not just a coverage function. In industrial automation, roaming is a control transition. On a skillet line, the mobile unit moves predictably along a known path. The system typically knows the skillet position through barcode readers, zone sensors, or other position-tracking mechanisms. This creates an important opportunity: roaming does not need to be triggered by degraded signal strength. It can be triggered by known process events or physical position.

This is a major difference between standard Wi-Fi roaming and deterministic industrial roaming. In signal-strength-based roaming, the system reacts after the radio condition has already changed. The client may decide to roam only once the current connection becomes weak.

In contrast, event-based roaming allows the system to prepare the next connection before the current one becomes critical. For skillet lines, this means the wireless system can know in advance when a mobile device will cross from one subnet or radio segment into another. The roaming process can be prepared, authorized, and executed at the correct position in the production flow.

This is the basis of zero latency roaming.

ZERO LATENCY ROAMING PRINCIPLE

Zero latency roaming means that the communication transition is prepared before the mobile device needs to rely on the next radio segment/subnet. The actual switch is therefore reduced to a deterministic, scheduled, and controlled event. In the following, a roaming sequence from Subnet 1 to Subnet 2, with anchors (a.k.a. access points), barcode-based position information, and mobile nodes on the skillets. The process can be summarized in four steps (see the figure below and figrues next page).

Step 1: Position-triggered switch request

In the example, as Mobile 3 approaches the defined switching position, its controler sends a request to switch to Subnet 2 to its momentary assigned Anchor 1. Anchor 1 forwards the request to target Anchor 2.

Step 2: Resource reservation and data rerouting

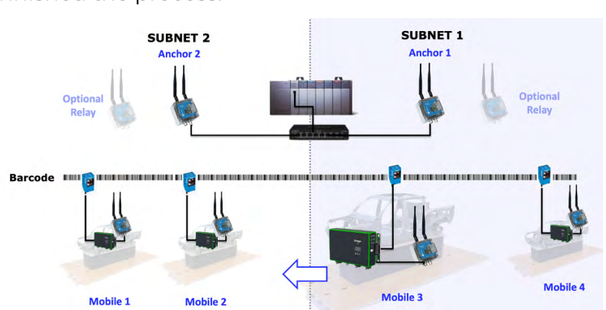
Anchor 2 reserves communication resources for Mobile 3 in the target subnet. In a token-based system, this means that a communication is reserved before the mobile device actually completes the transition. At the same time, traffic for Mobile 3 is rerouted from Anchor 1 to Anchor 2, such that it is immediately available in the target subnet, once Mobile 3 has finished the process.

Step 3: Mobile transition preparation

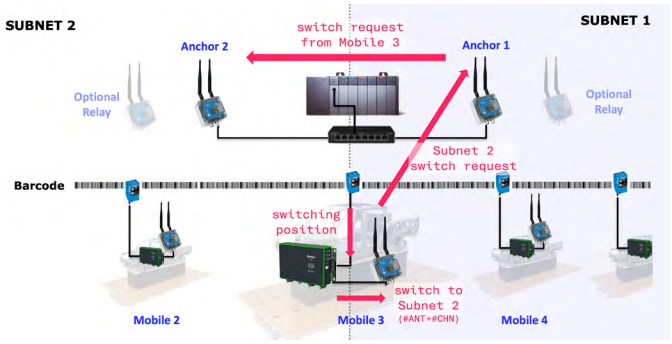
Anchor 1 informs Mobile 3 that access to Subent 2 was granted. The mobile unit waits for the next token to check out from Subnet 1.

Step 4: Transition

Mobile 3 completes the transition by sending a GOOD BYE message after receiving its last token in Subnet 1. It then waits for its first token in Subnet 2 to send a HELLO message and continue regular data exchange. From the application perspective, communication remains continuous because the roaming event was prepared before it became necessary.



Simplified network setup with skillets relying on barcode readers.



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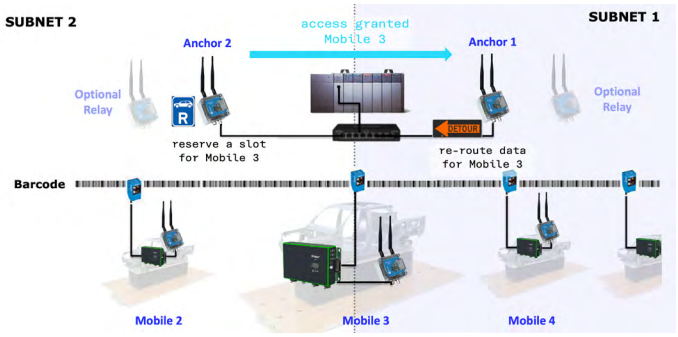
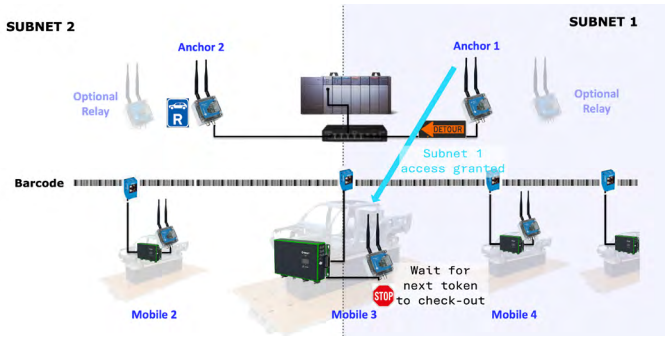
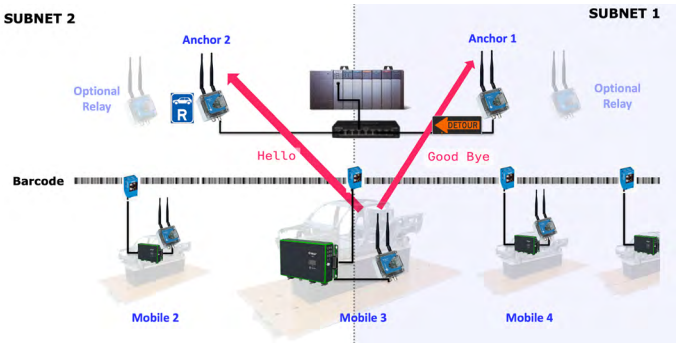


Step 2: Resource reservation and data rerouting



Step 3: Mobile transition preparation



Step 4: Mobile transition preparation

The four steps of the deterministic position-tiggered roaming sequence in a token-based communication network

KEY TAKEAWAYS

Assembly line skillets are commonly connected using conductor line bus systems, slotted waveguides, or leaky coax. These technologies have proven useful, but wireless communication is becoming increasingly attractive where flexibility, reduced mechanical wear, and easier installation are required.

However, wireless communication for skillet control is only feasible when the wireless system supports deterministic behavior. Standard Wi-Fi does not provide deterministic medium access or deterministic roaming by design. A Bridge E network with EchoRing addresses these requirements by providing:

- deterministic medium access,
- deterministic event-based roaming,
- fast login beyond conventional fast roaming,
- event-based antenna switching,
- error correction at low cycle times,
- interference robustness,
- industrial data prioritization,
- operation as a dedicated OT network in parallel with IT Wi-Fi,
- support for safety and control data traffic.

Zero latency roaming is therefore not only a roaming optimization. It is a system architecture for maintaining continuous control and safety communication while mobile production units move through an industrial automation line.

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