TECHNICAL BRIEF

Creating Advanced Handover Test Systems with Low-cost RF Devices

The latest in USB and Ethernet programmable Lab Bricks can be used to create even complex, multipath fading simulations.

In order for modern wireless communication networks, including 4G LTE, 5G, and Wi-Fi, to operate to an acceptable reliability and user experience level, they must successfully complete handovers in a variety of scenarios. With the expansion of wireless connectivity to virtually every aspect of modern human interactions, providing an uninterrupted connection is a necessity for device manufacturers and network operators. Soon, the ability to complete successful handovers within and between wireless networks may become a necessary safety feature for currently in-development autonomous vehicles, transportation, and delivery systems.

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Handover phone calls are a higher priority to new calls in a cellular network as the seamless transition between cells is critical to the quality of service.

A handover, or handoff, occurs when an outgoing cellular connection is transferred from one cell to an adjacent cell while the user equipment is moving through the network coverage area.

Handover in Theory

A handover, or handoff, occurs when an outgoing cellular or other wireless communication connection is transferred from one cell/router to an adjacent cell/router as the user equipment is moving through the network coverage area. Cells are physical areas with cellular coverage provided by a cellular broadcast tower, while other wireless communication technology, including urban 5G, has other ways of determining the boundary between coverage areas. Handover is used with cellular or other wireless networks, such as industrial LTE/5G or Wi-Fi networks. There is an increasing demand for seamless handover between a variety of wireless communication services, that is also driving the need to efficiently perform handovers within a network and between wireless networking technologies.

In the case of cellular networks, the cellular radio hardware is designed to operate with multiple frequency channels to optimize the quality-of-services (QoS) to a variety of different user equipment in different environments. This complicates handovers somewhat, as the handover system in wireless networks with multiple frequency channels must handle the physical transition of the user equipment as well as possible transitions between bands. Handover can also occur between "sectors" of the same cell, known as intra-system handover. Sectors are different areas of coverage from the same cellular base station, and multiple 'sectors' can occupy one 'cell'. Hence, there are a variety of different handover conditions.

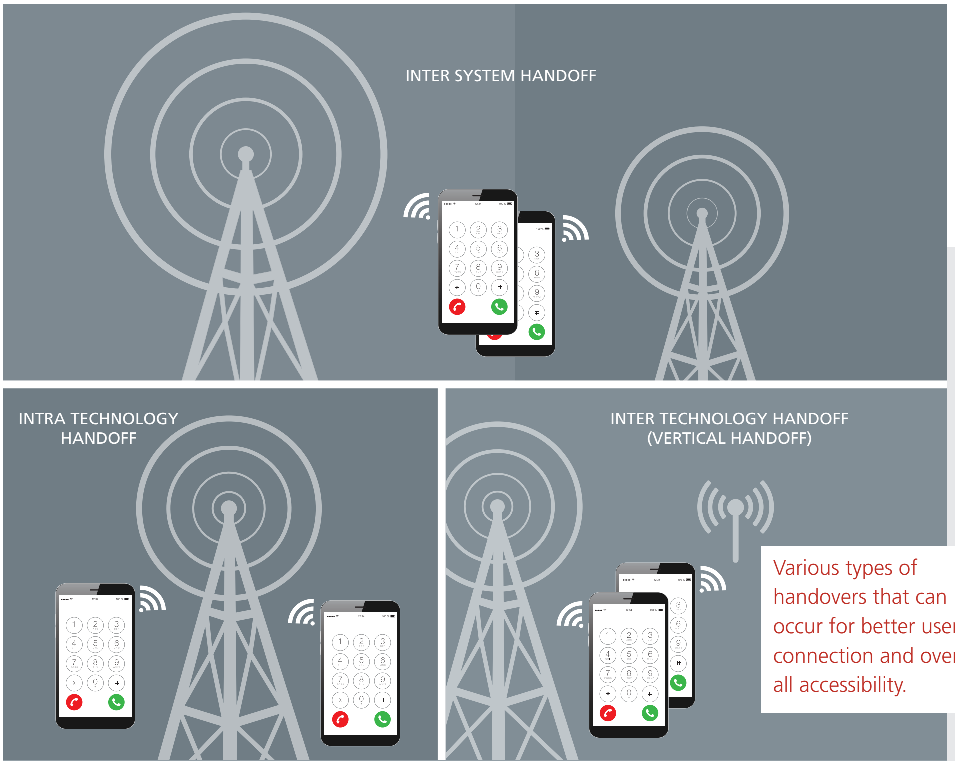
Soft handovers, for instance, were developed for the goal of providing a seamless call transition in cases where a cellular connection becomes unreliable due to fading. Where fading is the natural weakening of a received radio signal due to attenuation in the environment. A soft handover occurs when a connection to the current cell is only broken after a steady connection to the target cell is established, known as 'make-before-break'. On the other hand, a hard handover occurs when the mobile connection from the source is broken and the connection to the target is made afterwards. This type of handover is also known as a 'break-before-make'. Hard handovers allow for a more efficient use of a wireless network's frequency channels as only one channel is necessary to enable a hard handover.

Relying on hard handovers simplifies the design of the user equipment as it also does not necessitate the need for parallel processing of several channels. While soft handovers can require more channels and user equipment that can receive two or more channels in parallel, the chances of a signal in all the channels being interrupted is much lower. In other words, dropped calls are highly unlikely in soft handover networks.

Inter-system handover can often occur with highly mobile user equipment, such as a smart car or passenger user equipment in high speed public transit, where the target connection is established from one cell to a completely different cell or base station. More recently, cellular technological advances have enabled vertical handover, such that a mobile phone connects between cellular networks and wireless LAN (WLAN) for greater accessibility. While cellular networks can offer lower data rates over large areas, WLAN technologies can potentially compensate for this as it offers higher data rates over smaller areas.

Technology	**GSM**	**CDMA/ UMTS (3G)**	**LTE (4G)**
Received Signal Level	Rxlevel	RSC P	RSRP
Received Signal Quality	RxQual	Ec/Io	RSRQ/ SNR
Channels	BCCH TCH	PSC	PCI

With the advent of 5G technology, this thinking has changed somewhat. 5G networks can now offer speeds comparable to WiFi networks, but the deployment, licensing, and access to user equipment are what make accessibility to user equipment between the two networks attractive. There has been discussion and proposals to eventually converge Wi-Fi and cellular communication standards to create a more harmonious wireless user experi-



Various types of handovers that can occur for better user connection and overall accessibility.

ence for cell phone users, as well as Internet-of-Things (IoT) and machine-type devices.

The new diversity of devices and wireless communication standards is creating an environment where quality connected user experience is a power differentiator, and there is an impetus for device manufacturers and network operators to support seamless connectivity experiences for users and devices regardless of location, mobility, or device type. Considering the ongoing development of ultra-reliable low-latency communication (URLLC) and massive machine-type communication functionality with upcoming standards of 5G, the need for seamless handovers is also becoming an issue of safety and device utility and not just one of user experience. For these reasons, device manufacturers and network operators need modular and reconfigurable methods of performing handover tests to effectively simulate real-world conditions with a greater degree of accuracy than ever before.

How Do Basic Handovers Work?

Legacy Cellular Handover

For basic, legacy cellular networks, network engineers generate a 'neighbor list' of potential target cells for handover from selected source cells. Then, as a call is ongoing, the source channel's signal transmission strength is monitored to assess when a handover request by the mobile phone of the base station is necessary. In this complex process, the base stations in the 'neighbor list' and the mobile phone are connected and monitor each other for the best target cell to connect to.

Network engineers have enabled several monitoring methods to ensure handover takes place seamlessly. The parameters that are tracked are dependent on the types of network modes that the mobile phone receiver and base station antenna is communicating with—some of these modes include GSM, UMTS, LTE, and CDMA. Ultimately, the received signal level and

received signal quality is tracked in the network measurement reports (NMR). Although, this is more complex with vertical handover where metrics should include user preference, network conditions, application types, cost, etc. In GSM networks, the RX level indicates the power level of the received signal and is measured in decibels (dBm) and RxQual is an integer value representing the quality of voice at the receiver. The integer value of RxQual corresponds to the number of bit errors in a number of bursts. For UMTS, the received signal code power (RSCP) is another measurement of received signal power over a communication channel, and is measured in dBm. The Ec/Io is the ratio of the received energy per chip and the interference level measured in dB. In LTE handover measurements, the reference signal received power (RSRP) is used to estimate path loss, while reference signal received quality (RSRQ) indicates the quality of the received reference signal. In essence, RSRQ is a ratio between RSRP and the reference signal strength indicator (RSSI).

5G, Wi-Fi, LTE and Future Handover

Where traditional cellular handover was typically performed between cells, with relatively slow moving user equipment, and were mainly configured to handle voice communications, modern and future handovers include many more factors and a diversity of communication types. Modern and future handovers are being tasked with handling high speed data communications, sometimes with IP preservation, and increasingly with enhanced robustness to better serve URLLC and massive machine-type communications (mMTC).

With 5G in particular, handover is now being handled as a special case with a new procedure, reconfiguration with sync. This occurs when the radio link has been degraded, either from the downlink or uplink side, and the needed measurement data can't be communicated between the mobile terminal and the network. In order to prevent these occurrences, additional handover protocols have been developed, such as conditional handover. In this new method, the cell currently connected to a mobile terminal preloads a handover command to the user terminal with the necessary conditions to initiate a handover prior to the radio link becoming inoperable. The network then also preemptively prepares other nearby cells for the potential need for a handover, so if the radio link fails both the mobile terminal and an optimal cell are both ready to initiate a handover. Therefore, a conditional handover is able to handle moderate speed mobile terminals transitioning between cells and other fast paced conditions where legacy handover is most challenging.

This is an example of how handover is evolving with cellular communications, but new handover techniques, methods, and protocols are being explored and standardized for virtually all major wireless communication standards based on networks. As mobile terminals/user equipment now contains more wireless networking features than legacy devices, and will likely continue to include additional wireless networking capability, handover testing for mobile terminals and evolving network technologies will only continue to become more complex.

technology to better handle a variety of common handover conditions, that include fading/multipath fading simulation. Handover testing requires both profiles that emulate real-world conditions and also hardware that can respond to the specifications in the testing profile and synthetically alter the environment of the radio link(s) as seen by the network technology to accurately capture the test conditions. This can include altering the signal strength among many paths, changing the delay (phase) of the signals, and otherwise accounting for a diversity of network topologies and connection scenarios.

Fading and Multipath Fading Simulation

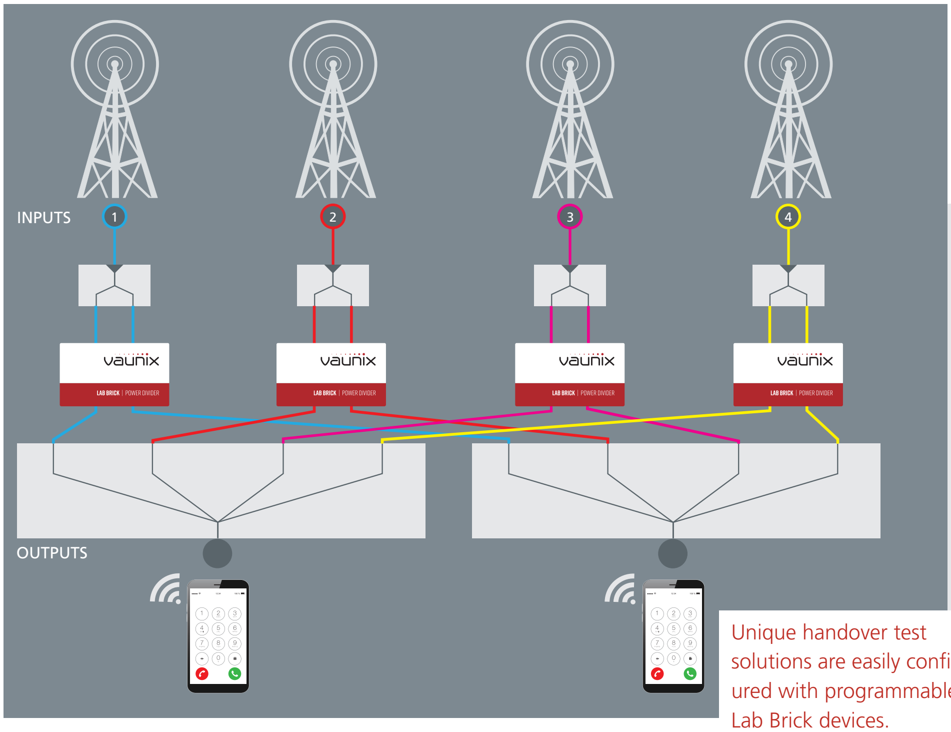
Fading is the effect of broadcasted signals being attenuated and dispersed by various media in the environment. As a result, the transmitted signal is broken up into multiple paths. Each resulting copy of the transmitted signal has varying amplitudes, delay, and phase shift while traveling from the source to the receiver. Shifting frequencies can also occur when the target receiver is moving causing a doppler effect. The type of multipath induced fading is a vital component in assessing the quality of a wireless network, as it frequently occurs in real environments and therefore requires an engineering solution.

Fading simulators are employed in wireless network tests to simulate the random multipath fading process. The International Telecommunication Union (ITU) and 3GPP/LTE, for instance, provides standardized methods and

Handover Test

Handover testing is the crucial stage of development of network hardware, software, and protocols where the wireless network performance is evaluated under controlled simulation of real-world conditions. This allows for more optimal design and/or configuration of wireless networking

The more digital attenuators, the more interconnected paths between ports in a test set-up.



Unique handover test solutions are easily configured with programmable Lab Brick devices.

guidelines to simulate environments that generate multipath fading issues. These guidelines include environments, such as urban, suburban, and rural area simulators. The mathematical models of the random process of fading have evolved into several fading profiles including rayleigh, rician, lognormal, and others. There are a variety of techniques to apply these fading simulators in a test environment, with the most popular being leveraging a vector signal generator (VSG) with digital baseband inputs and fading options.

Modularity is the Key

Fading is a significant factor in handover testing as it is often a cause of handoffs. Another potential cause of handoff is a target simply moving out of the range of coverage for a particular cell. Sophisticated protocols and modeling are already in place, not only to simulate fading, but to also monitor received signals in time for a seamless handover. It is important, however, that hardware for testing these protocols remain modular to maintain a level of customization as these technologies are constantly evolving.

One element of a handover test system is the digital/programmable attenuators, which are able to reduce the transmit/receive signal strength within the network to simulate fading or obstructions. Other key elements of a handover test system may also include phase shifters, RF switches, and power combiner/dividers. With phase shifters inline a handover test system, signal delay can be mimicked up to the phase shifting range of the device. Power dividers and combiners along with switches enable a highly configurable handover system that could potentially be reconfigured to accommodate a variety of test scenarios or even test various wireless network technologies.

What is extremely important in a modern handover test system is to be able to accommodate several terminal devices and network terminals simultaneously. Also, with the advent of Wi-Fi 6e and extended Sub-6 GHz 5G frequency bands, legacy handover test systems that only operate to ~3 GHz with limited physical channels are no longer adequate to test modern 5G and Wi-Fi networks. This is where modular attenuator matrices, switch matrices, and high port-count power dividers/combiners that reach to 6 GHz and over 7 GHz for Wi-Fi 6E are becoming increasingly sought after. With the faster pace and increased vertical integration of wireless networking technology, more modular, configurable, and low-cost handover test systems are needed for device manufacturers and network operators to deliver the best user experience and most robust network possible.

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Next Steps:

Learn how Vaunix Digital Attenuator Handover Test Systems bring affordability, functionality, reliability and simplicity to the microwave test bench.

Read our spotlight on Fluidmesh's success in implementing a Lab Brick Attenuator to resolve a mobillized Wi-Fi handover challenge.

Download our Tech Brief on 5G MIMO Networks and Test Methods

Visit our Support Page for our additional technical resources and to request application assistance.