Comcast's 4G/5G Cloud-Enabled Citizens Broadband Radio Service (CBRS)-Based Private Network Solution

Implemented at THE PLAYERS CHAMPIONSHIP®

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1. Introduction

Enterprises of all sizes require reliable wireless connectivity to help power their business operations. Large public events relying on wireless solutions can become capacity-constrained. Applications required at such events can include streaming applications for displaying content throughout the venue, push-to-talk applications to enable real-time communication among employees and staff, and quick-response (QR) code-scanning applications for various types of admission control. To support these scenarios and fulfill the capacity-focused applications, Comcast Business developed a fourth generation (4G)/fifth generation (5G) cloud-enabled citizens broadband radio service (CBRS)-based private network solution.

Although each application mentioned above can provide challenges, generating and disseminating video streams throughout an enterprise or venue can present one of the more interesting challenges.

In this paper, Comcast describes how it used its 4G/5G cloud-enabled CBRS-based private network at The Players Championship 2024 which was a PGA Tour golf tournament held at TPC Sawgrass in Ponte Vedra Beach, Florida from March 14-17, 2024. The private network distributed ultra-high-definition video feeds to cloud-based streaming servers for content aggregation and subsequent distribution using multicast technology. The infrastructure delivered live video streams to multi-panel kiosks for real-time onsite viewing parties and a cloud-based portal for those viewing via the Internet.

2. Solution Overview

For The Players Championship 2024, Comcast needed to deploy a private wireless network solution that collected live footage from various viewpoints around the golf course indoors and outdoors with little or no existing network infrastructure. Adding to the challenges, Comcast received access to the TPC Sawgrass venue only ten days before the event commenced. On the same timeline, contractors started installing equipment to support the common networking infrastructure such as high-speed Internet access.

At The Players Championship, Comcast's CBRS-based private network delivered low latency, ultra-high-definition video streams to demonstrate the power of CBRS spectrum and private wireless networks, leveraging priority access license (PAL) and general authorized access (GAA) CBRS spectrum. Comcast provided access to real-time streaming video content, offering a behind-the-scenes look at The Players Championship's inner workings.

With its advanced network, Comcast was able to quickly deploy a private network across indoor and outdoor locations throughout the venue, with the only required on-premises equipment being the radio infrastructure itself. Additional resiliency was added to the cloud-based combination 4G/5G core by deploying a local, on-premises core as a backup designed to mitigate any unforeseen technical issues experienced with the Internet or public cloud infrastructure.

The high-level architecture of the deployed solution is shown in Figure 1. The left-hand side of the figure depicts equipment installed locally on the TPC Sawgrass grounds and facilities. The right-hand side of the figure shows the cloud-based systems that were used (on multiple public cloud service providers), in addition to related support systems. Additional details of the solution are provided in the subsequent sections.

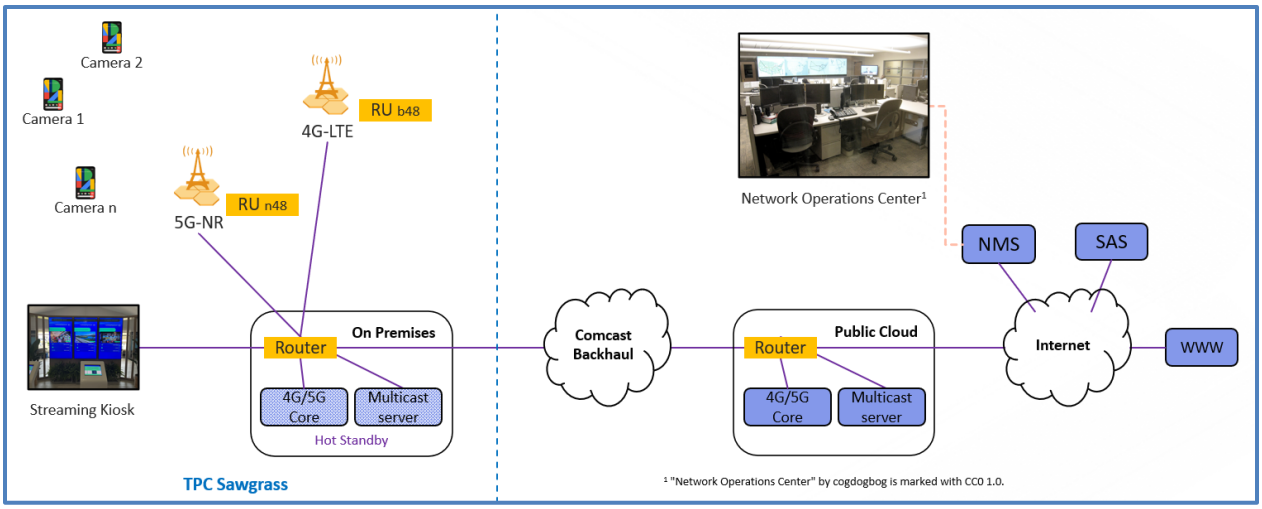

Figure 1 - High-Level Architecture

3. Private Network Solution

Major components of Comcast's 4G/5G cloud-enabled CBRS-based private network solution are described in the forthcoming sections.

3.1. Application(s)

As mentioned above, one of the most challenging use cases for venue-based scenarios is to stream live content from multiple locations around the venue. For its streaming application, Comcast selected a multicast streaming partner that it has used previously for a similar solution, with a proven ability to deliver low-latency video over cellular wireless network connectivity. For the 4K video streams, Comcast selected commercial handsets from a leading device vendor upon which they installed the required streaming application.

During the integration and testing phases, Comcast configured some handsets for long term evolution (LTE) 4G connectivity only and some for 5G new radio (NR) connectivity only. For the live event, Comcast configured all devices for both LTE and NR CBRS cellular access. This provided the ultimate flexibility as devices could be moved as needed to various locations, and they would automatically select the most optimum CBRS network signal.

In addition to the streaming application, Comcast's private network solution can support other common venue-based applications. In similar venue-type scenarios, Comcast has leveraged its 4G/5G cloud-enabled CBRS-based private network to enable staff venue communication via push-to-talk applications as well as ticket scanning via QR applications for admission control at gates located at the edge of the venue.

3.2. Radio Access Network

For the CBRS radio network, Comcast selected radio access network (RAN) products designed for private network and enterprise-level deployments. The main advantages of these types of products over the traditional macro cellular network products are that they typically are low power (including power over ethernet), have smaller form factor and lower weight, and have an integrated antenna system. All these factors combine for relatively fast and simple physical installations.

As part of its overall solution, Comcast decided to deploy both 4G and 5G base stations in both indoor and outdoor form factors throughout the venue. Indoor versus outdoor units were selected based on the physical location of the base station. For example, at The Players Championship, indoor units were used inside physical structures, and outdoor units were used in exposed areas such as tee boxes, fairways, and greens. 4G versus 5G radio units were selected and deployed primarily to highlight the different technologies in a single integrated solution.

3.3. CBRS Spectrum

In 2015, the Federal Communications Commission (FCC) made the CBRS band available for *shared* commercial use in the 3.5 GHz frequency band (3550-3700 MHz) [1]. CBRS has a three-tiered access and authorization framework to accommodate shared use of the band as summarized in Table 1 below.

Table 1 - CBRS Three-Tiered Access

Tier	Type of Access	Description
1	Incumbent Access	- Includes authorized federal users in the 3550-3700 MHz band, Fixed Satellite Service earth stations in the 3600-3650 MHz band, and grandfathered wireless broadband licensees in the 3650-3700 MHz band - Receives protection against harmful interference from PAL and GAA users
2	Priority Access	- Consists of PALs that are licensed on a county-by-county basis - Each PAL consists of a 10-megahertz channel within the 3550-3650 MHz band; PALs are a 10-year renewable license
3	General Authorized Access	- Allows open access to the band for the widest group of potential users - GAA users can operate throughout the 3550-3700 MHz band but must not cause harmful interference to Incumbent or Priority Access users

At the venue, Comcast held PAL for 40 MHz of CBRS spectrum which, with proper radio frequency (RF) planning, could support the high-speed bit rates required for the 4K streaming application. However, the spectrum channel allocation between uplink and downlink subframes was different from a typical fixed wireless application (FWA) because the handsets were *generating* large amounts of data, instead of consuming it.

For example, for FWA applications typically used to provide high-speed Internet access, it is common for CBRS radios to use the downlink/uplink configuration ratio of 4:1, i.e., four subframes are configured for downlink data and one subframe is configured for uplink data. At The Players Championship, the CBRS radios were configured with a 3:2 downlink to uplink ratio nearly doubling the uplink capacity to support 4K video streaming data rates.

To provide production against interference from PAL and GAA users, a geographic region called a dynamic protection area (DPA) is defined. DPAs are dynamically activated and deactivated based on incumbent activity in the area. When activated, the spectrum access system (SAS) suspends a set of grants so that the aggregate (PAL and GAA) is below the National Telecommunications and Information Administration (NTIA) defined interference margins [2].

Upon review of historical DPA activity in the area, Comcast identified multiple DPAs in the months leading up to the event being held at TPC Sawgrass. To mitigate the impact of any potential DPA activity on the CBRS-based private network during the live event, Comcast decided to configure both PAL and GAA CBRS spectrum on its CBRS radios. Comcast configured the radios such that the PAL spectrum was used as the primary spectrum and the GAA spectrum was used for backup.

3.4. Backhaul Design

When designing backhaul for the radio access network (RAN), Comcast decided to configure S1-Flex between eNodeBs (base station radios for 4G) and the 4G core and next generation (NG)-Flex between the gNodeBs (base station radios for 5G) and the 5G core. *S1-Flex* allows an eNodeB to have multiple S1 connections to the 4G core's mobility management entities (MMEs); *NG-Flex* allows a gNodeB to have multiple N2 connections to the 5G core's access and mobility management functions (AMF). In practice, S1-Flex and NG-Flex are used to provide control plane redundancy between the RAN and core.

To support the data speeds required for 4K video, Comcast decided to use 1 Gbps connections for its backhaul links between the eNodeBs/gNodeBs and the Internet router(s). The physical locations of the eNodeBs and gNodeBs were determined based on available infrastructure mounting points (e.g., structures, poles, buildings, spectator stands, trucks/vans), the location of the desired video cameras throughout the venue, and the corresponding RF plan that was created to provide coverage throughout the venue.

3.5. 4G/5G Core Network

To support both 4G and 5G and to provide a highly redundant private wireless solution, Comcast decided to deploy a hybrid combination 4G/5G core. A *hybrid* core is one that is deployed both on-premises and in the cloud. A *combination* 4G/5G core is a core that supports both 4G and 5G components.

To communicate with RAN components, the combination core must support both S1-MME and N2 for the respective 4G/5G control plane interfaces and support S1-U and N3 for the respective 4G/5G user plane interfaces.

Notes:

The S1 application protocol (S1-AP) and NG application protocol (NG-AP) are similar *protocols* used for 4G and 5G control planes, respectively.

The *protocol* used for the 4G and 5G user plane interfaces is the same, i.e., general packet radio system (GPRS) tunnelling protocol user plane (GTP-U).

Similarly, from an Internet/data network connectivity perspective, the combination 4G/5G core must support both SGi and N6 from their respective gateways, i.e., the packet data network gateway (PGW) and the user plane function (UPF). The underlying network layer communications protocol typically is internet protocol (IP).

Figure 2 provides a high-level diagram of a combination 4G/5G core showing the key interfaces between the RAN and core, and core and Internet.

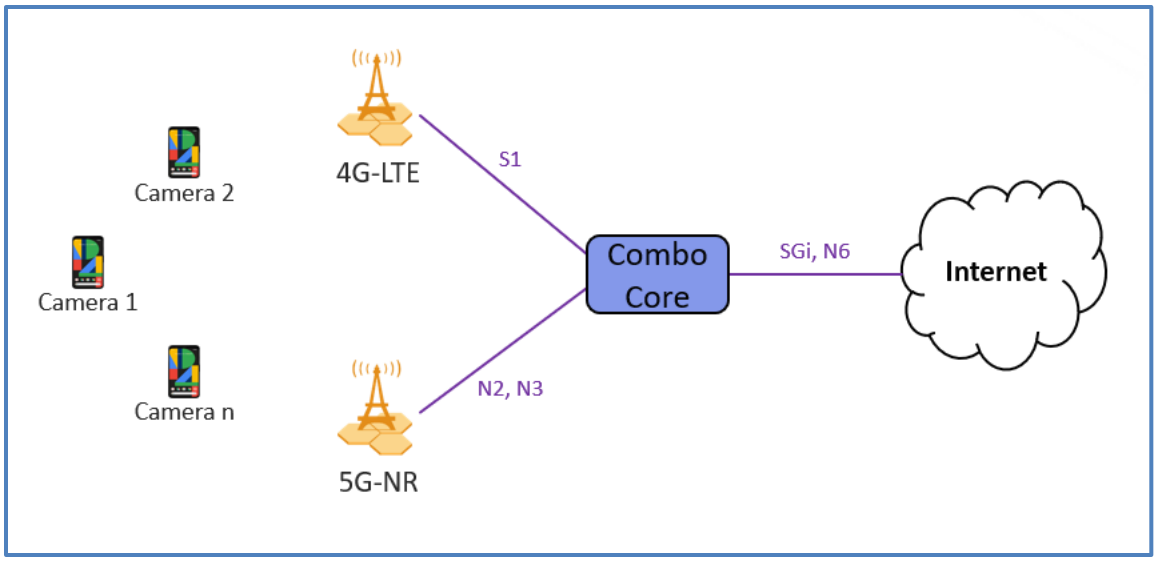

Figure 2 - Combination 4G/5G Core

Table 2 provides a high-level comparison of the 4G and 5G nodes/functions. Interfaces within the 4G and 5G cores are also different and must be supported by the combination 4G/5G core. Table 3 provides a head-to-head comparison of the more common 4G and 5G interfaces.

Table 2 - 4G/5G Functional Comparison

Item	4G Device/Node	5G Device/Node
User equipment	UE	UE
RAN node	eNodeB	gNodeB
Control plane	MME	AMF + SMF
User plane	SGW + PGW	UPF
Subscription data	HSS	UDM/UDR
Policy	PCRF	PCF
Authentication	MME	AUSF

Table 3 - 4G/5G Interface Comparison

Interface Between	Node A	Node B	LTE/EPC	NR/5GC	Description
UE and radio access network	UE	eNB, gNB	Uu	Uu	Air interface
RAN and core – control plane	eNB, gNB	MME, AMF	S1-MME	N2	Mobility control
RAN and core – user plane	eNB, gNB	SGW, UPF	S1-U	N3	User plane
User plane gateways	SGW, UPF	PGW, UPF	S5/S8	N9	GTP packets
Gateway and "Internet"	PGW, UPF	"Internet"	SGi	N6	User data
Control plane and gateway	MME, SMF	SGW, UPF	S11	N4	Session control
Policy server and enforcement node	PCRF, PCF	PGW, AMF	Gx	N15	User policy

Additional information on the 4G/LTE and NR/fifth generation core (5GC) system architectures can be found in 3rd generation partnership project (3GPP) technical specifications, 3GPP technical specification (TS) 23.401 [3] and 3GPP TS 23.501 [4], respectively.

3.6. Cloud Infrastructure

The underlying infrastructure of the Comcast private network solution leverages a Comcast-enhanced instance of public cloud infrastructure. Most of the centralized functions of a Comcast private network solution are hosted on the public cloud infrastructure. For the private network solution used for The Players Championship, the primary combination 4G/5G core and the multicast 4K streaming server(s) were hosted in a public cloud.

User traffic (i.e., 4K streams from the video capturing devices) from the venue to the public cloud was transmitted over the user plane interfaces between CBRS RAN and combination 4G/5G core using Internet Protocol Security (IPsec) tunnels which added data security. After the packets were processed by the 4G/5G core, they were sent to the cloud-based streaming server(s) which used multicast technology to distribute the video content to listening clients (i.e., venue kiosks and Internet-based subscribers).

4. The Players Championship

For The Players Championship, Comcast leveraged its 4G/5G cloud-enabled CBRS-based private network solution to bolster wireless connectivity at the event, powering a real-time video streaming application for fan engagement as shown in Figure 3 below. This multi-panel streaming display shown below was set up in one of the hospitality suites on the TPC Sawgrass golf course a few days before the event started.

Comcast also multicasted the live streams to similar displays in its customer experience center located in Philadelphia and the same content was available to Internet-based subscribers via browser technology. In each of the viewing scenarios, end users could select one or more of the live views being streamed from TPC Sawgrass on a multi-panel display.

To showcase Comcast’s public cloud-based private network solution, Comcast streamed all content using its public cloud-based combination 4G/5G core and multicast stream servers. Onsite on TPC Sawgrass

grounds, the delays between the live action and the video streams being shown on the multi-panel streaming display were negligible.

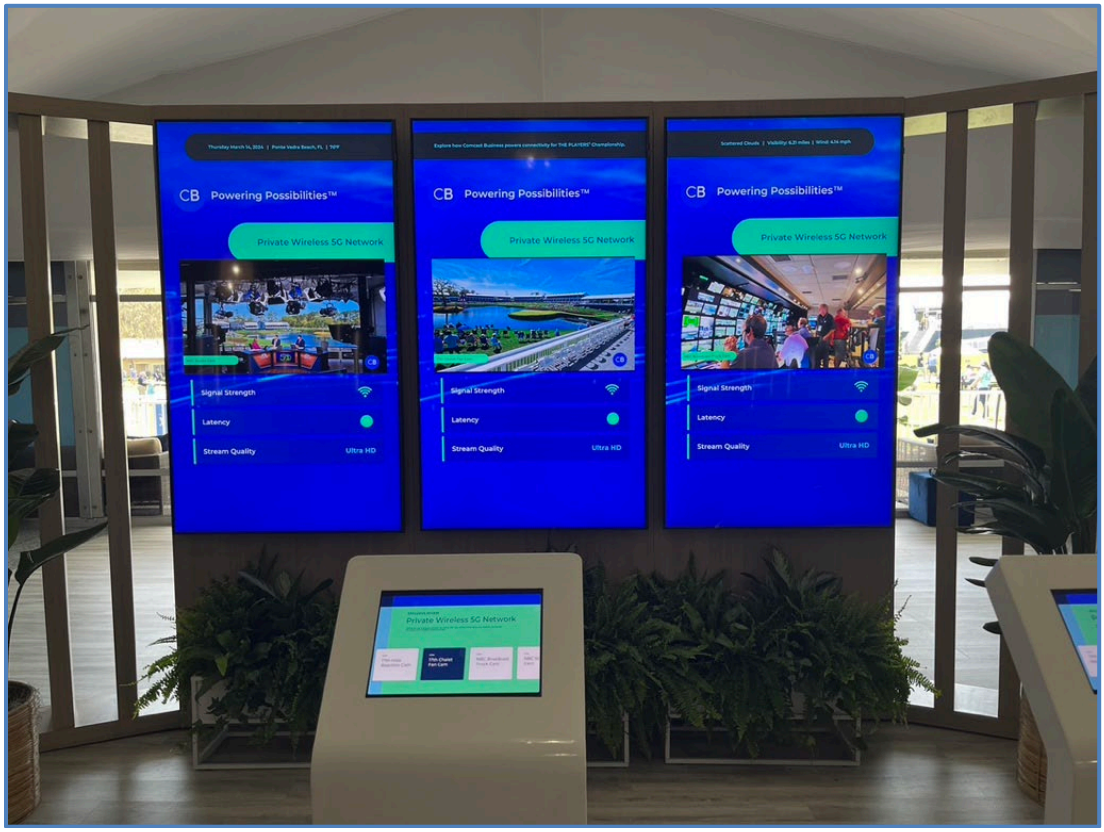

Figure 3 - Multi-Panel Streaming Display

5. Conclusion

Comcast's primary objective for The Players Championship project was to demonstrate reliable, high-speed wireless connectivity at a premier sporting event.

While public cellular and Wi-Fi may experience capacity and coverage challenges, Comcast's CBRS-based private network provided services throughout the event without interference or interruption. Comcast delivered seamless, reliable, high-speed wireless connectivity in the most demanding of situations.

Comcast received significant press coverage on this project as part of an over-arching technology deployment to power The Players Championship [5, 6, 7]. While quantitative metrics are not publicly available from this demonstration, Comcast's solution delivers low latency and high reliability, particularly in high-density, high-usage environments.

Throughout the event, Comcast's 4G/5G cloud-enabled CBRS-based private network performed well and provided the ultimate user experience, meeting and often exceeding expectations. Due to the overwhelming success of the project, Comcast plans to leverage its CBRS-based private network solution for future opportunities that are similar in scope.

Abbreviations

3GPP	3rd generation partnership project
4G	fourth generation
4K	4K (video resolution of 3840x2160)
5G	fifth generation
5GC	fifth generation core
AMF	access and mobility management function
AP	access point
AUSF	authentication server function
CBRS	citizens broadband radio service
DPA	dynamic protection area
eNB	eNodeB (evolved NodeB)
EPC	evolved packet core
FCC	Federal Communications Commission
FWA	fixed wireless application
GAA	general authorized access
Gbps	gigabits per second
GHz	gigahertz
GTP	general packet radio system (GPRS) tunnelling protocol
GTP-U	general packet radio system (GPRS) tunnelling protocol user plane
gNB	gNodeB (next generation NodeB)
HSS	home subscriber server
IP	internet protocol
IPsec	internet protocol security
LTE	long term evolution
MHz	megahertz
MME	mobility management entity
NG	next generation
NG-AP	NG application protocol
NR	new radio
NMS	network management system
NTIA	National Telecommunications and Information Administration
PGW	packet data network (PDN) gateway
PAL	priority access license
PCF	policy control function
PCRF	policy and charging rules function
QR	quick-response
RAN	radio access network
RF	radio frequency
S1-AP	S1 application protocol
SAS	spectrum access system
SGW	serving gateway
SMF	session management function
TS	technical specification
UDM	unified data management
UDR	unified data repository
UE	user equipment

UPF	user plane function

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