Applicant:	Sacramento Downtown Arena LLC (AKA G1C) Collaboration with XCOM Labs
File Number:	0924-EX-CN-2021

Exhibit Information

(A) Complete program of research and development proposed including description of equipment and theory of operation.

The project is a collaboration between the Golden 1 Center (G1C) and XCOM Labs on the prototype evaluation of a 4G/5G distributed MU-MIMO system for high-capacity, ultra-dense deployment in a sports stadium using the CBRS band.

XCOM has developed an advanced coherent distributed MIMO system for dense wireless deployments. The network is based on a distributed RAN architecture (also referred to as C-RAN) based on O-RAN standard interfaces. Remote radio units (RRU's) are connected via fiber front-haul to a baseband unit (BBU) implemented using COTS servers. Unlike conventional distributed antenna solutions (DAS), the capacity ideally scales with the number of RRU's per cell via a combination of advanced dynamic interference management and interference optimized beamforming. The technical approach allows multiple users to be schedule simultaneously with the same time-frequency resources while minimizing the interference between users.

The goal of this project is to validate and optimize system performance of this approach for a novel hyper-dense, hyper-capacity stadium deployment. The trial test-bed of distributed RRU's shown in Figure 1 combined with centralized processing (equipment located in IDF under stadium) enables hyper-dense deployment using low power under seat RRUs. With this approach RRU density of approximately 20-30 seats/users are achieved. For comparison the legacy cellular deployments in the stadium cover 1000 seats/users per cell (effectively an RRU).

An initial prototype based on LTE 20MHz TDD was developed by XCOM. This system has been trialed/tested using a testbed deployed at G1C under experimental license (0407-EX-CN-2020). A second generation proto-type system has been developed based on 5G NR supporting 100MHz TDD. Basic functional performance has been validated using cabled and limited scale indoor testing under the granted experimental license (711-EX-CN-2020) at XCOM labs.

The goal of this project is to field trial the technology using the identical G1C testbed (same RRU locations). The proposed system/trial will scale performance by at least 10-20x in terms of system capacity. The ability to characterizes the hyper-dense system performance in a real-world scenario during games with high user density, channel dynamics and loading is invaluable to both validate and demonstrate potential system performance. From a relative technology performance perspective, the ability to compare/contrast system performance for IDENTICAL deployments is critical to substantiate relative system performance gains to legacy technology.

To support full bandwidth 5G NR 100MHz testing, the application is full 100MHz of contiguous spectrum within the CBRS band (note previous license was granted for 50MHz which was sufficient for LTE 20MHz testing).

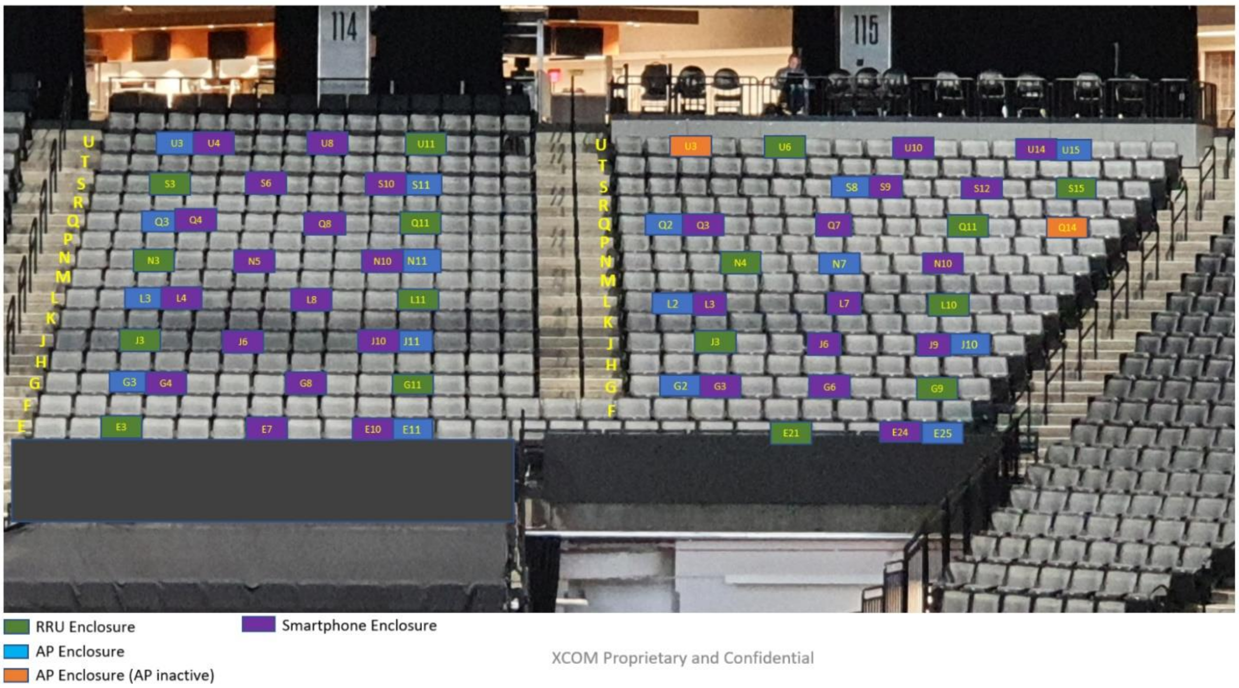

Figure 1. Trial test-bed system in Sacramento Golden One Center (G1C). Green boxes are locations of RRU's.

The requirements for operation in the CBRS band are specified by Part96. To satisfying coordination requirements and interference avoidance to incumbents the procedures and interference analysis is as follows:

Coordination with SAS

- XCOM has contracted Federated Wireless to provide SAS coordination. Federated Wireless SAS will provide daily monitoring and alerts to flag any co-existence issues. On receipt of an alert, operation will be suspended until the next SAS report/recommendation is provided by Federated for available channels / ERIP levels. This system was successful used for experimental license (0407-EX-CN-2020).

G1C is a controlled indoor deployment.

- Golden One Center IT team manages the systems deployed in the arena. Operation on the CBRS band is verified to not conflict or impact the commercial indoor systems operating in the stadium. The indoor deployments are as follows:
  - Cellular 2G/3G/4G system (for AT&T, Verizon, T-Mobile and Sprint) deployed over various frequency bands below 2.5GHz. This system is deployed using indoor DAS.
  - Verizon 5G system deployed over mmW band (>28GHz).

    - The police and fire department relay 27Mhz and 400-500Mhz.
    - G1C currently use 400-500MHz – internal 2-way radios.
    - G1C Wi-Fi (802.11ac/ad) system over 2.4GHz band and 5GHz band.
- Any CBRS deployment within the stadium would be coordinated with the G1C IT management. XCOM labs coordinates with G1C. This is another level of protection beyond the SAS which will also provide alerts for potential coexistence conflicts.

Interference to incumbent and commercial operations including GAA.

- The SAS provides the primary interference coordination (indoor and outdoor) and as noted above there is no current CBRS deployments within the stadium.
- An additional level of outdoor interference avoidance to PAL/GAA is ensured by isolation. The testbed system operation is limited to indoor G1C section 114 and 115, located at the lower-level bowl (inner ring of stadium seating).
- Measurements have been conducted to quantify the isolation (attenuation) and interference level to the nearest outdoor coverage locations. See Figure 2.
- The emission (interference) level is less than 201 uV/m. This is below the FCC General Emission Limit of 500uV/m (refer to FCC Emission Part 15 Subpart C 15.209 & 15.205). See Figure 3.
- Any interference in the band is at a level below the spurious emission limits of 500 uV/m, thus avoiding interference by being below the required level.

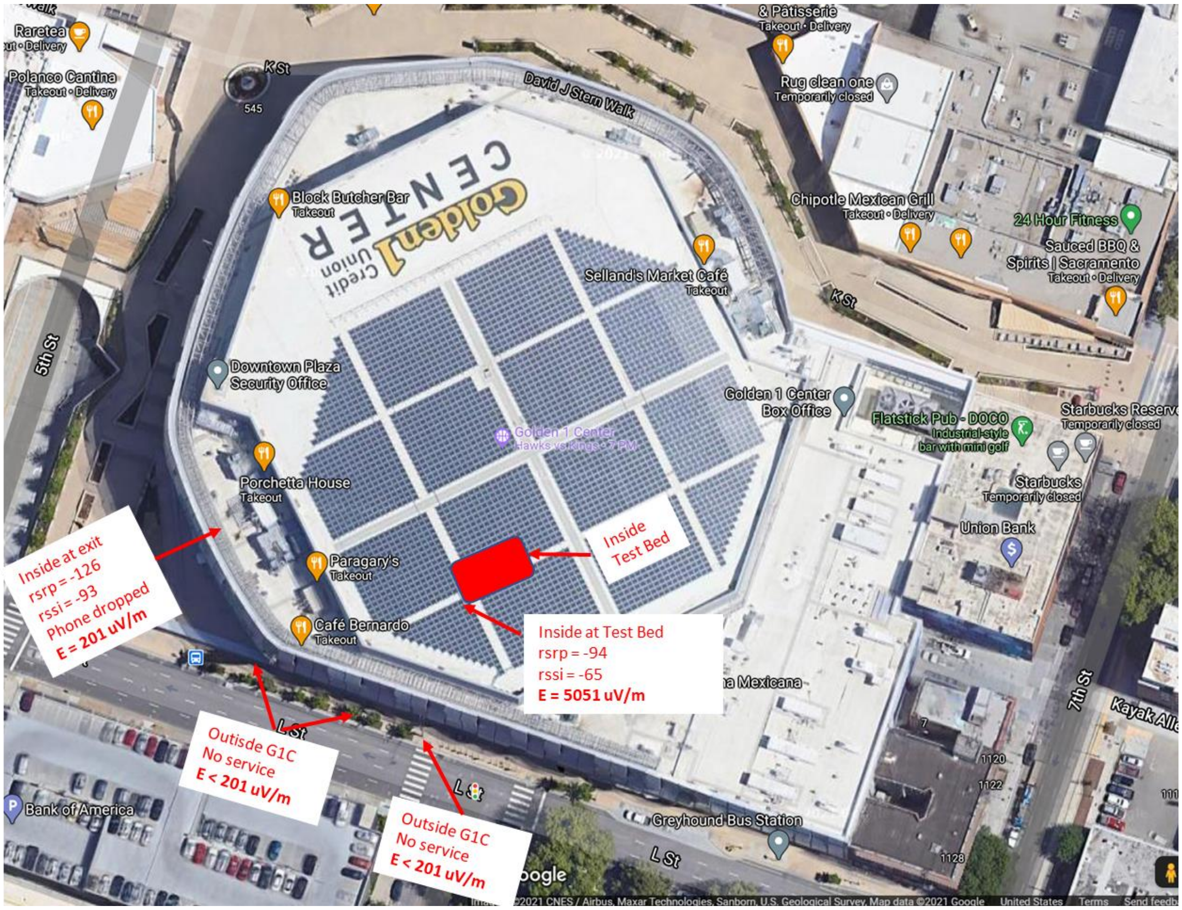

Figure 2. Measurement test locations relative to the indoor testbed (highlighted).

Part 15 Subpart C 15.209 & 15.205

Frequency(MHz)	Field strength(microvolts/meter)	Measurement distance(meters)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F(kHz)	30
1.705-30.0	30	30
30-88	100	3
88-216	150	3
216-960	200	3
Above 960	500	3
Remark: The emission limits shown in the above table are based on measurements employing a CISPR quasi-peak detector except for the frequency bands 9-90kHz, 110-490kHz and above 1000 MHz. Radiated emission limits in these three bands are based on measurements employing an average detector, the peak field strength of any emission shall not exceed the maximum permitted average limits specified above by more than 20 dB under any condition of modulation.		

Figure 3. FCC General Emission Limits.

(B) Specific objectives sought to be accomplished.

Practical implementation of distributed MU-MIMO also referred to as coherent COMP has many technical challenges especially in real-world scenarios. A number of technical challenges were identified and addressed based on the initial LTE 20MHz testing using the G1C testbed. For 5G NR the goal is to push the envelope of performance in both the spatial, frequency and modulation order dimension. Though similar to 4G LTE, there are a number of changes/enhancements in the 5G NR specification. It is expected there will be similar practical (and unexpected) challenges when we move from the lab to the field.

The objectives of the trial system are

1. Distributed MU-MIMO channel estimation and modelling – the field system enables real-time capture of complex multi-point and multi-point channels. Real-world data on channel dynamics up to 100MHz bandwidth is critical to evaluating performance of reciprocity based coherent precoding techniques.

2. Distributed MU-MIMO over-the-air calibration – the field systems allow validation and experimentation of our calibration techniques. Joint calibration of ALL RRUs is critical to system performance. Under real-world scenarios shadowing, path loss will limit RRU to RRU visibility. Experimentation is required to validate calibrations procedures.

3. Distributed MU-MIMO scheduling – the field system allows validation of advanced L2 algorithms required to group users for spatial multiplexing. Experimentation is required to validate algorithm performance in real world user density and loading.

4. End-user performance testing – compare and contrast system performance to baseline 4G systems.

5. End-user application testing – there is significant interest in validating system performance for "next generation applications", specifically AR/VR applications. The test bed will eanble real-world end-2-end testing and feasibility demonstration of the high-performance (high throughput) and low latency applications.

(C) How program of experimentation has reasonable promise of contributing to the development, extension, or utilization of the radio art, or is along the line not already investigated.

With the 5G revolution and the advent of centralized processing architectures; distributed MU-MIMO also referred to as coherent COMP is technically feasible. However, to-date deployments have been limited to traditional non-distributed MIMO. The objective of this program is to deploy and evaluate under real-world conditions distributed MU-MIMO. As outlined in the objectives section there is significant experimental work to be completed to validate and optimize this new paradigm. Given such deployments do not exist today it is not a simple evolution of an existing system (e.g. 5G massive MIMO). The distributed MU-MIMO approach is a natural capacity enhancement to the shared cell approach (DAS). If successfully validated, it is expected this approach will offer significant gains in spectral efficiency for deployments that prioritize coverage and capacity. The approach is uniquely suited to challenging indoor deployments that either require hyper-dense user density and/or the coverage of an indoor DAS system but the capacity of a massive MIMO system.