(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.

The traditional approach for robust indoor cellular coverage is typically in the form of a distributed antenna system (DAS). Also referred to as a shared-cell, multiple remote radio units (RRU) multi-cast the downlink signal and combine the up-link signal for each cell. While the coverage of the system is a function of the number of RRU's, the capacity does not scale with number of RRU's per cell. The existing cellular coverage within the stadium is based on a DAS system with approximately 1000 seats/users per DAS cell.

XCOM labs has developed coherent distributed MU-MIMO prototype over CBRS (3.5GHz) based on LTE-TDD 20MHz. The network is based on a distributed RAN architecture (also referred to as C-RAN) based on O-RAN standard interfaces. The RRU's are connected via fiber front-haul to a baseband unit (BBU) implemented using COTS servers. Unlike the DAS approach, the capacity 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 scheduled simultaneously with the same time-frequency resources while minimizing the interference between users. The technology enables hyper-dense under seat deployments with approximately 20 seats/users per RRU.

XCOM labs has completed lab validation of the system and plans real-world field validation. The proposed field trial deployment is shown in Figure-1. The system shadows both in density and enclosures to the existing hyper-dense under-seat Wifi deployment. The green squares are RRU locations – the purple are proposed test device locations. Extensive field trials are planned to evaluate absolute and comparative system performance under real-world scenarios (during game with high user density, channel dynamics and loading).

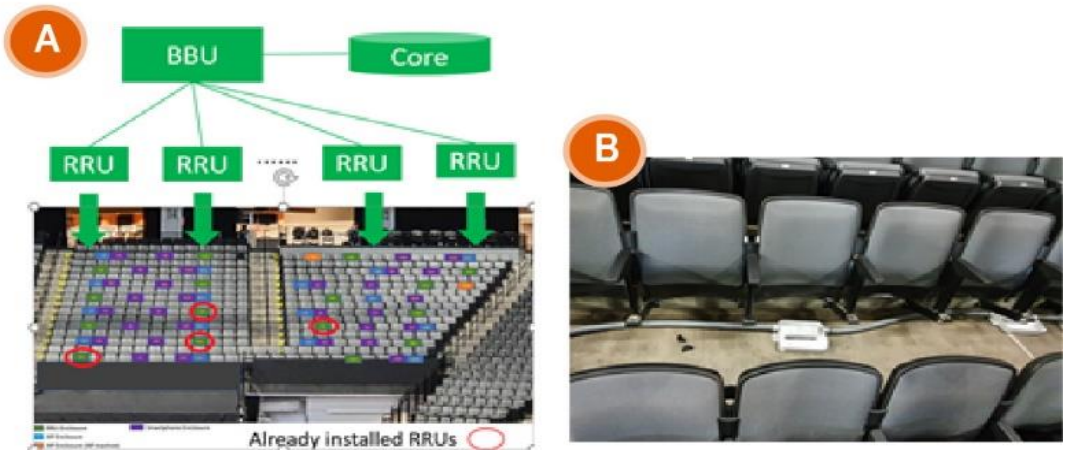

Figure 1. O-RAN based LTE Proposed Field trial system in Sacramental Golden One Center, (a) Trial site installation plan overview and (b) installed RRU and devices under seat

A marque feature of 5G/NR is up to 100MHz bandwidth operation at sub 6GHz. A key aspect of this program is to evaluate system performance over the supportable bandwidths. The G1C is an indoor stadium deployment and the wireless deployments within the stadium are coordinated by G1C. As part of this request it is desired that the experimental license support operational bandwidth of 100MHz with appropriate restrictions. The initial LTE testing can be supported with operational bandwidth of 50MHz.

(b) Specific objectives sought to be accomplished.

Practical implementation of distributed MU-MIMO also referred to as coherent COMP has many technical challenges and the real-world performance has yet to be validated

The objectives of the trial system and testing is as follows:

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 allows validation and experimentation of over calibration techniques. Joint calibration of ALL RRU's 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 systems 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 application testing – compare and contrast the system performance to the DAS cellular and hyper-dense Wifi underseat system.

(c) How program of experimentation has reasonable promise of contributing to the development, extension, expansion or utilization of the radio art, or is along 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 (eg LTE to 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.