

## Research Assessment Exercise 2020

### Impact Case Study

**University:** The Hong Kong University of Science & Technology

**Unit of Assessment:** 12 - electrical & electronic engineering

**Title of case study:** Commercialization of wireless technology through a startup company, IEEE standard and patents

#### **(1) Summary of the impact**

██████████ pioneering research on wireless communication technology has had quantifiable commercial impact during the census period. This includes (1) the development of commercial products and the employment of engineers by a startup company that utilized their background technology; (2) an IEEE standard in force that they made background contributions to and (3) patent licences.

#### **(2) Underpinning research**

The group has a long history of pioneering research in the area of wireless communications. Several of its contributions to the field have had significant impact.

First, **Multiple Antenna Technology** was pioneered by the research group, which is recognized as one of the earliest developers of Multi-User Multiple Input Multiple Output (MU-MIMO) technology [1,2]. This technology is now used in Wi-Fi (IEEE 802.11ac) as well as 4G-LTE (Long Term Evolution). The motivation for MU-MIMO was the realization that mobile devices can only have a limited number of antennas while base stations, given their size, can have many antennas. To overcome this limited antenna constraint on mobile devices, the group developed MIMO techniques that could serve multiple users each having only a few antennas using a MU-MIMO configuration. These techniques increased overall capacity while meeting practical constraints. The group developed several early approaches to MU-MIMO [1], including antenna techniques [2]. They were one of the first to publish in this area. Their work has been well cited (see references). The techniques were first adopted in the uplink of Wi-Fi IEEE 802.11n systems and subsequently in Wi-Fi 802.11ac and 4G-LTE systems.

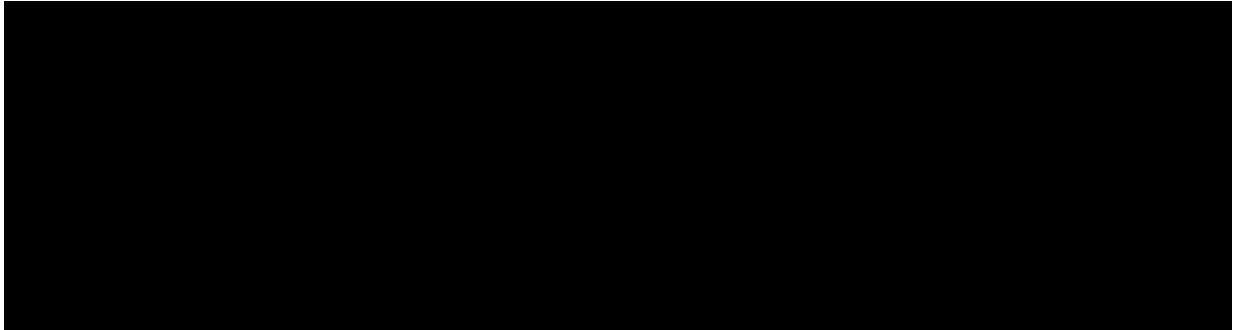
Second, the group conducted research into **Cognitive Radio (CR)** early in its development. A CR is an intelligent radio that automatically senses and detects available channels in the radio spectrum and dynamically uses the best wireless channels in its vicinity to minimize interference and maximize throughput. A key characteristic of CR is that it can share radio spectrum with other systems. It therefore has the potential to unleash significant spectrum when other systems are not using their allocated spectrum. A key CR area that the group contributed to was spectrum sensing. Approaches developed included energy sensing and energy sensing in clusters [3,4]. The technology they developed was the basis for four contributions that are included in the IEEE 802.22 Wireless Regional Area Network Standard, which was published in July 2011 and remains in force to this day

Finally, the group pioneered **limited feedback in wireless systems** [5, 6], which is an essential component of 4G-LTE, IEEE 802.11 and future 5G wireless systems. It is widely known that employing channel adaptive signalling in wireless communication systems can yield large improvements in almost any performance metric. Unfortunately, many previously proposed channel adaptive techniques were deemed impractical because of the problem of obtaining channel knowledge at the transmitter. The motivation of the limited feedback design is to achieve the benefit of adaptive signalling to combat wireless fading channels while at the same time taking into account the practical constraints of the limited radio resource available on the feedback channels. The group provided a holistic study of the field of limited feedback wireless communications: from fundamental theory to practical implementation considerations [5,6]. The design of limited

feedback has become a key technology component in modern wireless standards that make use of MIMO, CR, modulation and coding.

### (3) References to the research

The six papers listed below were the starting point for the impact that our research has created. Taken together, they have attracted over 3000 citations to date.



### (4) Details of the impact

The specific commercial impact of the group's research can be categorized into the following three main areas.

- *Start-up company*

The group's wireless communication research expertise and two background patents [REDACTED] co-invented by the group were used in the development of core products by a start-up company, [REDACTED]. This led to the employment of 20 engineers and the development of commercial products (including [REDACTED] basestation products) during the census period. In particular, our research on multiple antenna technology and limited feedback wireless systems was incorporated into [REDACTED] and [REDACTED] basestation products in a [REDACTED] system that provides enhanced throughput for more users as compared to their competitors' products. This system approach has enabled [REDACTED] to remain competitive over the census period. [REDACTED] states that 'The technology developed from these patents have allowed us to develop best-in-class products that have been crucial in allowing us to compete on the world market for the past 12 years and project contracts. This in turn has allowed us to build up a core team of over 20 engineers with expertise in the wireless, networking and cloud analytics domains' [REDACTED]. The former [REDACTED] states that 'Their help has contributed to the spin-out of [REDACTED] and the flagship products of [REDACTED] basestation... In my opinion the research contributions of [REDACTED] were world class and their results have produced prolonged impact to [REDACTED] and the wireless industry generally' [B]. Two letters of support [REDACTED] from these key personnel in [REDACTED] are attached in the Sources section. The two licensed background patents are listed below.



- *Standard contributions*

The group made four contributions [9-12] to the IEEE 802.22 Wireless Regional Area Network standard, which was published in July 2011 and remains in force to today, covering the entire census period. IEEE 802.22 systems provide wireless broadband access to regional, rural and remote communities. The 802.22 standard utilizes the CR and sensing of unused TV spectrum described in section 2 on underpinning research. The standard contributions are defined as mandatory and must be used in all equipment developed for the standard. They have been used for the implementation of products meeting the IEEE 802.22 standard during the census period. For

example, in 2014 the National Institute of Information and Communications Technology (NICT) and Hitachi Kokusai Electric Inc. successfully conducted the world's first field trial confirming long-range broadband communications in the TV white space at up to 5.2 Mbps over 12km by using IEEE 802.22-based systems[C]. The White Space Alliance (WSA) has defined the Wi-FAR interoperability specification[D], which is derived from the IEEE 802.22 Standard. Saankhya Labs produce the Meghdoot Base Station SLB802ODU and Dhaval Customer Premises Equipment Modem SLC802ODU, both of which are Wi-FAR compliant[E]. The four contributions made to the standard are listed below.



- **Patents**

During the census period, the research of the group resulted in four patented inventions, which were either co-invented with engineers at [REDACTED] or licensed to [REDACTED]. They have been integral parts of the patent portfolios of the respective companies during the census period, and continue assist with product protection to this day.

**(5) Sources to corroborate impact**

Letters of support and links to descriptions of impact are listed below:



[C] Press Release, World's First Breakthrough Achieved for Long-Range Broadband Communications in TV White Space January. 2014 [online – accessed July 2019] Available: <https://www.nict.go.jp/en/press/2014/01/23-1.html>

[D] White Space Alliance, [online – accessed July 2019] Available: <https://www.whitespacealliance.org/AboutUs.html>

[E] Saankhya Labs, Rural Broadband Products [online – accessed July 2019] Available: <https://saankhyalabs.com/rural-broadband/>

