

White paper

MIMO in the Metro

Radio Frequency Engineering
Connecting Asia's world cities



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Commuters on Hong Kong MTR's new West Island Line can enjoy uninterrupted wireless data at speeds of up to 600Mbps – thanks to MIMO and one of the world's most advanced confined coverage networks, designed and delivered by Radio Frequency Engineering (RFE), a BAI Communications (BAI) company based in Hong Kong.

These days most commuters like to utilise the time they spend either waiting for or riding upon public transport. Once limited to newspaper broadsheets or paperback books, the options for making every minute count continue to escalate in the 21st century with the functionality and speed of smart phones and tablets.

Whether it's catching up on business emails, online entertainment, social media or simply the news of the day, commuters increasingly expect uninterrupted wireless data access along the whole of their journey – including in underground stations and subway tunnels. Since outdoor cellular networks cannot

reach into these confined spaces, dedicated infrastructure needs to be deployed to propagate the signal within.

Hong Kong MTR Corporation (MTR) has long recognised this and has been a global pioneer since the first confined coverage communications system for passengers was deployed in 1993. Now, with the recent opening of the city's new West Island Line, a three-station and 3km extension of the MTR's Island Line, the MTR is once again leading the way.



One network, many challenges

Modern confined coverage infrastructure is typically founded on broadband distributed antenna systems (DAS) – comprising either a network of indoor antennas or radiating cables (leaky feeders) to deliver contoured coverage within a space. Some form of signal amplification is usually required to cover larger spaces and distances – for example, the signal may be transmitted over optical fibre to an optical repeater, which feeds a passive DAS.

A key feature of such systems is their broadband nature – they are typically designed to support the services of all commercial carriers, and often additional private radio and public safety services as well. As the number of RF services increases and new bands are utilized, the network design challenges just keep multiplying – especially as user demand and expectation escalate.

Hong Kong's West Island Line thus opened in December 2014 with what is believed to be one of the world's most advanced confined-space wireless coverage solutions. Designed and delivered by Radio Frequency

Engineering (RFE), the network is founded on a multi-band 2G, 3G and 4G (800-2700MHz) DAS featuring multiple input multiple output (MIMO) long term evolution (LTE) technology to markedly boost capacity and alleviate data traffic congestion.

The drive for higher capacity

Capacity, as much as coverage itself, is of critical importance in mobile network design – particularly in environments like the Hong Kong MTR, which experiences mass congregations of people with the time and inclination to use digital devices. Hong Kong's population is not only one of the most densely distributed, but also one of the most data-hungry, prompting the drive for new, higher-capacity 4G technologies such as MIMO.

MIMO is a method for effectively doubling the capacity of 4G LTE networks by using multiple antennas for both transmit and receive at the same time. Hong Kong's premier telecom services provider, HKT, which operates the city's leading mobile carrier, CSL, drove the incorporation of LTE MIMO into the West Island Line network, by means of carrier aggregation technology, to offer data speeds of up to 600Mbps per user*.

The result is shared network infrastructure supporting 2G, 3G and 4G services for all four of Hong Kong's mobile carriers – spanning CDMA (850MHz), GSM (900MHz and 1800MHz), WCDMA (850 MHz, 900MHz and 2100MHz), FD-LTE (1800MHz and 2600MHz) and TD-LTE (2300MHz). With the incorporation of LTE MIMO, the overall system is capable of delivering combined ultra-high cellular data throughputs of over 5Gbps.

The multi-band wireless coverage extends to all areas associated with three new underground stations – Sai Ying Pun (SYP), University (HKU) and Kennedy Town (KET) – along with approximately 3km of dual-bore tunnels. The station areas covered include the entrance gates to each station, concourse and station platforms, and passenger lifts at HKU and SYP stations – all designed to give commuters a seamless wireless data experience.

* Data throughput of up to 600Mbps only available to users with compatible LTE-A/Cat6 handsets.



Architecture and a half

The main challenge with MIMO in general is the much higher likelihood of interference occurring within the system, owing to transmitting and receiving simultaneously on the same cable and antenna network. This demands sophisticated network engineering to minimise interference, even for carriers' outdoor networks, which can be physically separated from each other. In the multi-band West Island Line confined coverage network, which supports all carriers' services on the same network (a total of 20 sub-bands spanning 800-2700MHz), the interference challenges associated with MIMO become significantly multiplied.

As a regional leader in the tailored design and integration of confined coverage systems, RFE was appointed to design and deliver the solution. The resulting network architecture is substantially more complex than previously deployed networks, requiring the highest quality standards in engineering design and installation to manage interference and maintain the strongest signal quality levels to achieve the data rate.

Each of the three new stations has a centralised point of interconnection to provide interfaces for the base stations of each commercial mobile service in Hong Kong. The signals from these base stations are combined and distributed via up to six sectors – tunnel #1, tunnel #2, concourse, platforms, long

entrances, elevators, and so on as required, with each sector covering the full 800-2700 MHz. The highest capacity network is HKU station, with six sectors deployed.

The broadband RF distribution system for each sector is either a radiating cable (tunnels) or indoor antenna network; many of these also incorporate fibre networks with multi-band optical repeaters

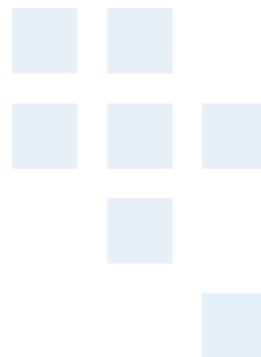
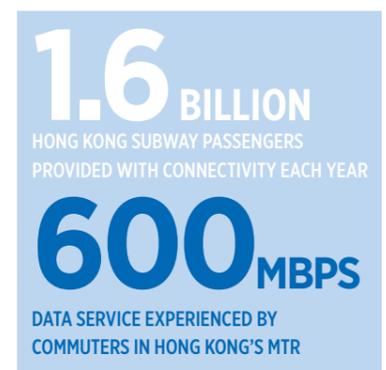
to achieve the required signal levels. The MIMO-compatible optical repeaters used in the West Island Line architecture were specially designed to meet the high capacity and power requirements of the system – as well as the high number of sub-bands. The entire system can support a traffic capacity of

The interference equation

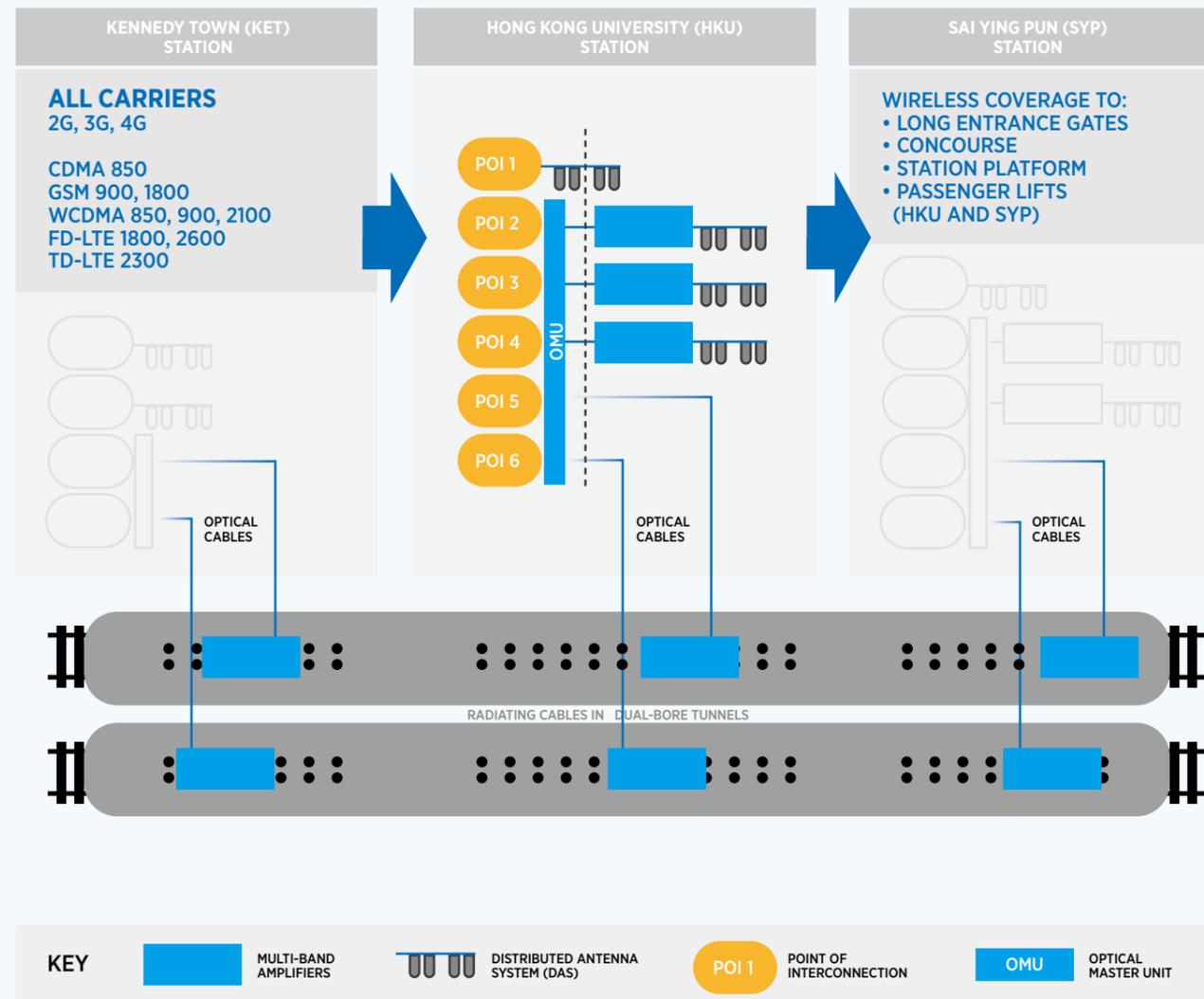
To manage interference in this complicated system, RFE carefully calculated the signal levels for all sectors that would result in minimum interference without affecting users. The network was then designed to deliver those precise signal levels, with high-performance filters added to all sub-bands.

An additional design challenge involved the positioning of antennas to exploit multipath propagation, which is used to control interference in MIMO systems. This is easier when antennas are spaced far apart, as in outdoor networks, a luxury not available in confined spaces. In tunnel systems, which incorporate radiating cables instead of point antennas, this is even more of a challenge.

To minimise the introduction of passive intermodulation (PIM), the system utilises the highest-performance equipment (including antennas, cables, repeaters, filters and connectors). This also demanded that installation crews deliver the highest-possible workmanship. During installation, each of thousands of connections was rigorously tested to ensure it met the PIM design specifications. Installation and commissioning took a period of three months, and included extensive testing of system performance inside a running train.



Data whenever they want



Anecdotal feedback from commuters suggests they welcome the quality of mobile data services along the West Island Line – from both a coverage and capacity perspective.

Indeed, it is undoubtedly one of the highest-capacity tunnel coverage networks in the world; not only does it support MIMO LTE for those with the most advanced handsets, but is compatible with all 2G, 3G and 4G commercial services in Hong Kong, spanning 20 sub-bands from 800-2700MHz. This is one of the highest number of services supported by a single broadband network.

Only those behind the scenes – in particular RFE and Hong Kong's commercial carriers, which identified the demand – will ever appreciate the high level of engineering required to get the network up and running. All commuters will experience is seamless data connectivity and the ability to check their phones and tablets whenever they want.



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