Solution Profile

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Cohere Technologies

The Potential Economic Impact of Cohere's Universal Spectrum Multiplier on Mobile Networks

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Introduction

As the demand for network bandwidth increases, the majority of mobile operators are evaluating advanced software technologies and optimization strategies to defer hardware capex during a complex and difficult economic climate, yet keep pace with, or even surpass, the growing need for capacity. The quality of network service relies on the strategic use of various spectrum bands, along with the enhancement of radio access technology. This includes the deployment across multiple frequency bands and the adoption of Multiple Input Multiple Output (MIMO) technology.

Cohere Technologies has invented a clever software solution to optimize spectral efficiency for existing 4G and 5G mobile networks, without the need to change existing hardware, antennas, radios or devices. It is a solution that has radical implications for telcos' capex and opex forecasts. As such, in this paper we evaluate the potential economic impact of Cohere's **Universal Spectrum Multiplier** on mobile networks.

Cohere's Universal Spectrum Multiplier (USM) is an advanced software application, integral to the operation of 4G and 5G mobile base stations, tasked with optimizing the use of available spectrum to accommodate the mobile devices linked to the base station. Its functionalities (Channel Sensing, Estimation, and Prediction) already exist today as part of the networks supplied by RAN vendors. But when wireless networks become congested, their current implementations leave operators with only expensive, time-consuming and disruptive options for addressing the problem, and in specific bands only (TDD), with massive MIMO only for higher frequencies. Cohere's technology promises a truly innovative solution to the issue, one that eliminates the costs of additional equipment and upgrades, such as cabling, antennas, or additional spectrum. It also puts in place mechanisms that will reduce the costs and disruption (of the wrong kind) associated with future network upgrades. USM is the industry's first MU-MIMO-enabling software for the majority of cellular bands: paired uplink and downlink networks (FDD) covering both low- and mid-band spectrum.

There is one fundamental, shared constraint that all mobile network operators must work within: **spectrum**. For wireless operators, spectrum is the essential, undeniable commodity without which there is no business. Hence, operators have been willing to spend increasing billions to secure it. In March 2021, US operators spent an *additional* $81bn to acquire C-band spectrum licenses. This is on top of the $44bn that US operators bid just five years earlier. The US government has raised $230 Billion in revenue via spectrum auctions.

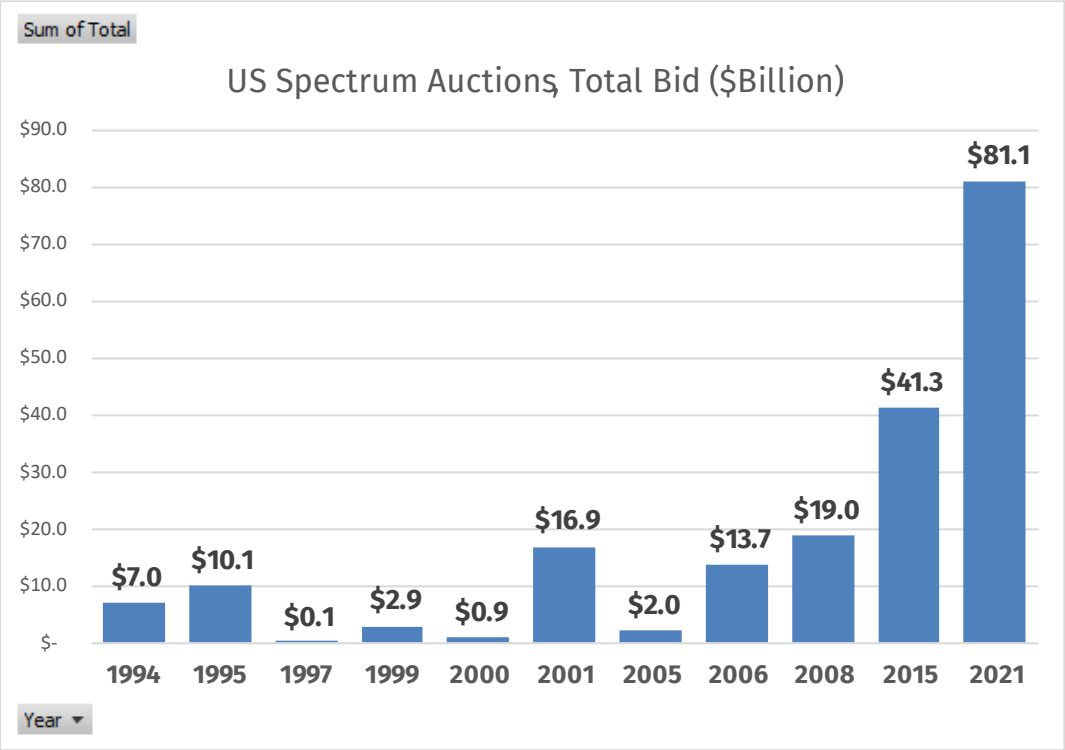
Different spectrum bands have different characteristics that make each one more or less suitable for a range of different applications. This also has a direct bearing on the type, quantity, location, and cost (both to buy and to maintain) of the network equipment used to deliver wireless services. It also significantly determines the quality of mobile service that wireless customers can expect to have.

As demand for wireless network capacity grows, this combination creates some serious business problems for network operators. First, since spectrum is a finite (and government regulated) resource, operators cannot create more of it as and when they need it. Second, making use of newly

available frequencies and bands means another major buildout program, typically funded by taking on more debt. Third, it isn't clear that customers will be willing to pay more, or if there is tangible ROI for the additional capacity.

A failure to resolve these issues is one reason why the telecom stocks have been flat for a decade, despite no letup in rising demand for telcos' services.

Figure 1: Spend on spectrum auctions, US telcos



Source: Appledore Research, FCC

But we are now in a unique period in the history of telecom. New technologies, new attitudes, new approaches are already in play that will come to define a new era in the performance of telecom operators. Operators *can* break the cycle of high capex, high opex, low return mobile networks. And the key to that lies inside every base station that mobile operators deploy (or have deployed!) today.

In this profile, we assess the business potential for operators of Cohere Technologies' Universal Spectrum Multiplier innovation.

About Cohere Technologies

Cohere was founded in 2011 by a highly distinguished and successful team of telecom veterans and pioneers with Shlomo Rakib and mathematics professor, Dr, Ronny Hadani. Its current chairman and CEO Ray Dolan joined in 2018 (formerly CEO at **Sonus Networks** and 4G innovator **Flarion Technologies**, acquired by **Qualcomm**).

To date it has received substantial funding (>$80m) from an impressive range of sources, including technology partners (**Intel**, **Juniper**, **VMware**) and, unusually, telecom operator venture funds (**Telstra**, **Bell Canada**), in addition to well-known venture capital firms (**Koch, NEA, Lightspeed**).

Cohere's involvement in industry standards and collaboration projects reflects the company's depth of technical experience, as well as their commercial savvy: industry innovation in telecom is generally slow, hardware-centric, and dependent on broad industry co-operation. Hence, Cohere's participation in the O-RAN Alliance, ONF, Telecom Infra Project, 3GPP and more.

Though Cohere's solution can be integrated into existing base stations in existing networks, the emergence of Open RAN has given a boost to Cohere's business by providing an additional route to market as an xApp on a near real time RIC hosted in a datacenter or as part of a hosted telco cloud (AWS, Azure)

In 2023, it launched the Multi-G initiative, along with **Intel, Mavenir, VMWare, Juniper, Telstra, Vodafone** and **Bell**. This collaboration will define frameworks, interfaces, interoperability tests and evaluation criteria that will enable 4G, 5G and future waveforms to coexist on the same infrastructure. The basic principle is to separate RAN intelligence and scheduling functions such that only a software upgrade will be required to allow a vRAN platform (such as Intel's widely used **FlexRAN**) to support future network technologies (waveforms). As CEO Ray Dolan has put it: "this will make networks programmable all the way from Layer 1 to the highest layers of the network."

The company has won numerous awards for its innovation (GSMA's GLOMO, Leading Lights, Fierce Telecom, Glotel, among others). Key vendor partners include Intel, Mavenir, VMWare, Juniper.

Cohere's offering is badged as USM – the Universal Spectrum Multiplier. For once, a product name that is perfectly descriptive.

Overview of USM

USM is a sophisticated software application that performs critical functions within a 4G or 5G mobile base station: determining how to make use of the available spectrum to serve the mobile devices connected to that base station. A version of these capabilities - Channel Sensing, Estimation and Prediction – is already built into the networks provided by RAN vendors. The issue is what happens in the event of congestion. Operators today have limited options. Cohere's technology promises a solution to the problem, without the areas of cost that are normally associated: no new cabling, no new antennas, no new spectrum.

When more is demanded than a cell site can support, calls are dropped, data packets are lost, impacting customer quality of service. Adding capacity means building out more infrastructure, and

replanning cell site relationships and coverage plans, which is a costly response also requiring much more time and effort.

Cohere's technology promises a more useful response: in the face of network congestion, it performs essentially the equivalent of opening up an extra set of airline check-in desks, additional lanes on a highway, or an additional floor of rooms in a hotel to accommodate a surge of customers. When the congestion subsides, the base station can revert to its default mechanism for allocating channel capacity.

Cohere is proving its technology with leading operators, including: **Deutsche Telekom, Vodafone, Telstra, Bell.** Appledore is aware of other unpublished trials.

In all these trials, Cohere's technology has been demonstrated to effectively increase the available capacity, by anywhere from 50% to 100% (2x) at a cell site – giving *multiple* users broadly the same capacity as if just a *single* user were being served. These trials have been conducted in low-band and mid-band (FDD) and including TDD (higher frequency).

Background: FDD & TDD

Historically, **Frequency Division Multiplexing** (FDD) is more commonly used by mobile operators. FDD dedicates separate frequency bands for uplink and downlink transmission. FDD is a good choice for voice-centric networks since the bands are symmetrical – allowing for equal up and downlink traffic. FDD bands are in the low-and mid-band ranges of spectrum such that they provide long range coverage.

Time Division Multiplexing (TDD) works differently, using the same frequency band for uplink and downlink, but changing the number of timeslots allocated to uplink or downlink *dynamically*. In principle, TDD allows for a more efficient use of spectrum, and a better fit for networks that carry bursty or asymmetric data. But it is more complex, requiring more computation and synchronization.

With the data-centric architectures of 4G and 5G, TDD is a more attractive path forward for operators, but it is still less common than FDD. Operators typically use a combination of both on their networks, balancing available spectrum, coverage, capacity and traffic profiles in a given area.

TDD is the more modern choice for high capacity 5G networks, with both AT&T and T-Mobile using TDD for their mmWave 5G networks, (though even Dish uses both FDD and TDD).

Cohere's USM works with both FDD and TDD networks.

Innovations

There are two key innovations involved. First is Cohere's breakthrough in how each base station figures out how much bandwidth to allocate and for how long, to each connected mobile device. Second, the use of MU-MIMO with orthogonal waveforms that allow the same frequency to be used to serve multiple connected devices at once, without interference, for existing networks - without the need to replace radios, antennas, or devices.

Technology Independent Channel Scheduling. Conventional spectrum modelling for channel measurement, scheduling and estimation uses a 2-dimensional Time vs Frequency model. Cohere's core innovation is to replace that with a 3-dimensional model that incorporates a spatial dimension (so-called Delay-Doppler modeling). Among the consequences of this approach are that the model becomes independent of the wireless technology or waveform – it is not frequency that is being modeled but the channel and its reflectors.

Zero-overhead Channel Estimation. USM makes use of existing handset/UE reference signals to inform the channel estimation model. This avoids the need for additional data or signaling, which acts to reduce available capacity.

Increased Channel Stability. The impact of channel aging (or fading) is also substantially reduced. Channel aging refers to changes over time in the accuracy of the channel estimate, caused by a range of factors: user movement, power, environmental conditions. Cohere's Delay-Doppler approach to channel estimation smooths out the sudden impacts that can affect time/frequency-based models, resulting in more stable and predictable channel estimates.

Operators have widely deployed MIMO (Multiple Input Multiple Output) technology – more and smarter antennas – as part of their network buildouts to improve service. For high density areas, MU-MIMO (Multi-User MIMO) increases the ability to support multiple users. On its own, MU-MIMO represents a relatively blunt instrument for solving capacity issues, somewhat akin to simply building more highways, where more intelligent traffic management would be a cheaper, faster and more effective solution. Cohere's Delay-Doppler model in MU-MIMO enables the formation of multiple beams in the most valuable FDD spectrum bands, orthogonally separated so as to avoid interference. No longer is MU-MIMO confined to TDD spectrum.

Effective Multiplication, not Sharing. Achieving higher spectral efficiency is important for operators. But techniques involve a tradeoff. Dynamic Spectrum Sharing (DSS) is another technology that allows the use of the same spectrum by multiple technologies (4G, 5G), adjusting the allocation according to demand and network conditions. DSS also uses Software-Defined Radios. But DSS requires a duplication of the scheduling function. The extra overhead also *reduces* the available capacity – in order to accommodate a wider range of end user devices. As more 5G devices come onstream, the benefits of DSS are significantly reduced. Essentially, DSS allowed mobile operators to turn up 5G networks on their existing spectrum – giving at least a modicum of substance to "first with 5G" marketing claims. But ultimately the difference is right there in the name: DSS is fundamentally a spectrum *sharing* solution, not a spectrum *multiplication* solution.

Deployment

There are three ways that operators can deploy Cohere's USM:

- Brownfield networks: as core software integrated with the existing base station (CU/DU).
- Greenfield (open RAN): packaged as an xApp on a RAN Intelligent Controller (RIC).
- Telecom Cloud: packaged as an xApp with a RAN Intelligent Controller (RIC) on an (AWS, Azure) Far Edge server.

For brownfield, implementation involves integration of USM at two points:

1. At the PHY layer (Intel FlexRAN is already a reference integration; OEM PHY layer stacks represent a custom integration).
2. As an integration directly into the DU or host the software adjacent to the DU and call it via a gRPC API.

(Appledore believes that the deployment option of an xApp on a Near Real-Time RIC is the least likely option in the near term.)

One interesting aspect of an implementation is that the spectrum multiplier functionality at the PHY layer only kicks in when triggered by spectrum becoming saturated. Existing base station functionality is used under non-saturated conditions. This means that operators need only add some additional tests to their conventional test suite for DU testing.

Cohere's USM software runs on commodity silicon - Intel CPUs – making a solution lower cost than proprietary embedded scheduling software.

Business Impact for Operators

Appledore sees multiple ways in which this technology can deliver substantial business benefit to telcos. Considering today's industry headwinds, all are of strong current relevance.

The most immediate value that Cohere USM provides is **solving mobile network congestion for low-band and mid-band FDD networks** - the great majority of all mobile networks today**.** Congestion is a business problem for telcos, every bit as much as a technical one. Congestion directly impacts customers' experience, and key indicators such as NPS. It also likely arises precisely because many customers *don't* have another option at that time and place – which adds to customer frustration. Telco executives looking to improve their **customer satisfaction** ratings (either subjectively as with NPS or objectively via network metrics) should assess the potential of Cohere USM.

Avoidance or deferring of capital spend. Especially with increased borrowing costs, future capital expense is a major concern for telcos. 5G rollouts are highlighting gaps in coverage that (on current plans) can only be addressed by additional network spend – and at time when the return from the existing spend is proving lacklustre. For example, if deploying the USM provides the necessary peak capacity and defers the deployment of a new Carrier Aggregation (CA) layer in the network, the operator immediately benefits from both customer satisfaction and long-term capex deferral.

With the *existing* network infrastructure already deployed (on 4G or 5G), Cohere USM means that operators can effectively upgrade available bandwidth to serve more customers, and at a fraction of the cost (and effort, and CO2 emissions, and legal work) of building out additional network infrastructure – i.e. extra base stations, antennas on towers, field engineering.

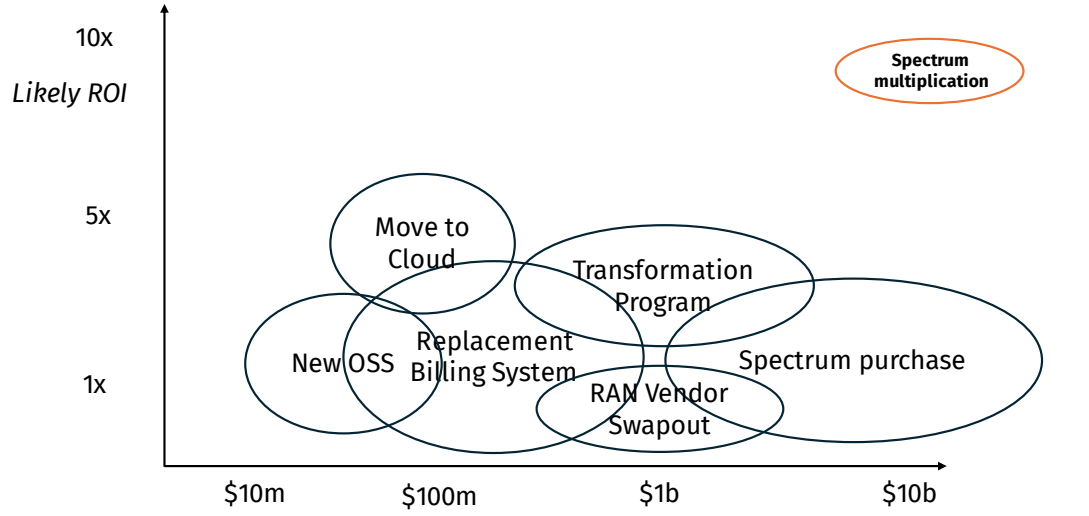
For a large operator, Cohere's figures put the capital expense *avoided* easily into the high hundreds of millions of dollars – if not more. For example, consider:

- A large US operator with 73,000 macro sites, each with an average of 3 sectors per site.
- Assume that 30% of macro sites need a Carrier Aggregation capacity layer. That means upgrades to 65,700 base stations and antennas.
- At anything above a (low estimate!) $15k per sector in average upgrade costs, an operator is already looking at **$1bn in network spend.**

Rather than protracted, painful vendor negotiations (and still ultimately a huge outlay) Cohere gives telecom CFOs a completely new (and substantially quicker and easier) near-term option: deploy USM as a software update to existing base stations and assess post-update capacity demands as an input to any (later) carrier aggregation plans.

Appledore sees few if any current initiatives in telecom that offer anything like the same level of return or ROI multiple (see Figure 2). Cohere's USM gives operators a new software-driven capacity increase that never existed before.

Figure 2: Relative ROI propositions for typical strategic telco initiatives (indicative)



Source: Appledore Research

Reduction in network TCO: Building and maintaining mobile networks is expensive. A visit to site, even to make a minor change, can be thousands of dollars. Responses to extreme (though increasingly frequent) weather conditions can easily consume all available field tech resources.

The calibration of network sites is typically a one-time activity, conducted by a field engineer with specialized test equipment, and only revisited in the event of a significant problem. Cohere's technology makes recalibration a continuous process, effectively re-using the data from existing customer devices to optimize the configuration. There are obvious comparisons in modern cars (not necessarily EVs) or aircraft, with engine management systems continuously and autonomously adjusting air/fuel mix, engine emissions, idle state, valve timing dynamically.

The ability to configure networks through software is already a significant industry trend. Appledore believes that this will be a major factor in reducing the cost of ownership in mobile networks.

Leveraging the cloud to reduce costs and increase flexibility. Robust channel estimation and prediction – modelled from a geometric perspective, these change more slowly, and therefore don't need the same degree of low-level processing (including custom silicon) to estimate in real-time. Software processing can achieve the same (better!) results, at a fraction of the cost. This means that the channel estimation scheduling can be decoupled from the DU in a base station – and instead locate the function in a telco cloud.

Increasing spectrum ROI. Increasing the value of a book asset: spectrum licenses. Cohere's technology makes it possible to serve as much as twice as many devices using existing spectrum. Even if the software is only deployed on a fraction of base stations, part of its effect is to raise the value of the licensed spectrum.

In the UK, the 2021 round of spectrum auctions cost the (then) four operators GBP1.36Bn (in 700 Mhz and 3.6Ghz bands). BT/EE paid most (GBP452m), then O2 (GBP448m), 3UK (280m) and Vodafone (GBP176m).

Reducing the cost and disruption of future network technologies. "6G" is an inevitability, but a high impact on 4G/5G infrastructure need not be. Accommodating 6G devices into an existing network may only require a software upgrade.

The increasing interest (and funding) of non-terrestrial networks (i.e. satellite-based) suggests that the future for operators will involve more, not fewer, network technologies. The focus in 6G on hyper-mobility also points to the need for more sophisticated ways to manage channels.

The Multi-G initiative spearheaded by Cohere with Intel, Mavenir, VMware, and Juniper extends the USMs Programmable Layer 1 PHY with two DU interfaces. This pioneering work will allow additional waveforms to coexist, and be spatially multiplexed, in any spectrum. While Open RAN is working towards the decoupling of RAN software from hardware, Multi-G is working towards decoupling waveforms from the spectrum. In the near future, USM equipped operators will be in a position to host the new 6G waveform within existing networks without disturbing the operational 5G waveform. And, they will add the 6G waveform via a software push and not an expensive and disruptive rip and replace project.

The Potential Economic Impact of Cohere's Universal Spectrum Multiplier on Mobile Networks

As we highlighted earlier, Cohere's USM has the ability to improve the economics of *every single base station* in a mobile network. Scaled up, this has implications for the future network hardware capex, the operational costs of field servicing, operational costs in detecting and diagnosing the impact of congested networks, and indirect costs such as dealing with customer issues or attempting to mitigate churn.

The nature of its innovation gives senior wireless telecom executives a significant new option for improving business performance in multiple key areas: customer experience, current opex, future capex. And to evaluate the business case, a CEO, CFO, COO need only ask questions that a CTO is already likely to have the answers to:

- How many cell sites do we have?
- How many suffer congestion? How often?
- By how many months (years) could we defer network capex, if we could add 50-100% more capacity to sites through a software upgrade?
- Which typically planned network upgrades (and associated capex) could we defer? For example, plans to go from 4T4R to 8T8R?
- How much are we predicting to spend on building out new wireless network to increase available capacity?

What is potentially in reach for operators is a 2-to-3-year postponement of plans to spend **hundreds of millions of dollars** in capital expenditure (likely raised by taking on additional debt).

Appledore sees additional parameters that operators should consider:

- What is the value to the business of extending the lifespan on current ("legacy"!) equipment and antennas?
- What is the potential return from winning new subscribers (with their associated ARPU) in competitive markets thanks to better service in congested areas – with no additional buildout?

Conclusion

Telcos are used to treating networks as inevitably large-scale, long term, high-capex projects. That has fundamentally shaped their commercial engagement models: long procurement cycles, multi-billion-dollar contract awards, coordinated to the beat of the mobile technology standards drum – 3G, 4G, 5G.

But we see signs that this is changing. "5G" is widely regarded as having been somewhat oversold, or at least not meeting the expectations for incremental revenue. As much as anything, 5G is causing telcos to reappraise their relationship with enterprises, and with suppliers who also serve enterprises. Partnerships and ecosystems are now in vogue, with collaboration and rapid market experimentation replacing the former certainty that adding more capacity leads to more revenue.

A preference for cloud, the establishment of more open, and programmable networks, are becoming more mainstream strategies. The consequences of this are – inevitably – a willingness to innovate in more fundamental ways, technical and commercial.

While we need to be careful with simplistic analogies, they are nonetheless useful in understanding the impact of highly technical innovations on the business and its customers. A 4-lane highway becomes an 8-lane one, overnight. A long-distance train service increases its frequency from once an hour to twice an hour. A car plant doubles its vehicle output, without increasing the size of the factory. A hotel doubles its number of available rooms – *without building a second hotel*! A driver suddenly sees half as much traffic on the road ahead, on her daily commute.

These are all, clearly, highly desirable outcomes, with substantial follow-on impacts for capacity management and planning, customer experience, business value and profitability.

Appledore regards Cohere's technology as truly revolutionary, and fully aligned with the fundamental changes that are defining a new era in telecom: programmable networks, more sophisticated software control and closed-loop automation, use of cloud computing for low-level telecom functions. And, perhaps most significantly, the opportunity to replace highly disruptive and capital-intensive G-cycles with more gradual, targeted, and smoother network upgrades, realized largely through updates to software.

Telecom CFOs, CEOs and COOs owe it to their stakeholders to consider the seismic and strategic business potential of this technology.

Insight and analysis for telecom transformation.

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