INDUSTRY UPDATE

TAKEAWAYS FROM MWC AMERICAS; CARRIERS CHOSE THEIR OWN 5G ADVENTURE

THE COWEN INSIGHT

Last week, we attended Mobile World Congress Americas in LA where 5G dominated the conference. IoT will create a new connectivity rev opportunity for carriers but at just 5% of the TAM, the real value creation will occur “up the stack” where carriers historically have not fared well and their strategies are likely to vary significantly from one another. Timing also remains of significant debate.

5G: The General Purpose Technology

5G was at fever pitch and we found that the commonly referenced 5G use cases (i.e. Fixed Wireless, Autonomous Vehicles, “remote surgery”, etc.) seemed stale/narrow-minded as various panels and floor exhibits showed the perservasive and profound nature of 5G, making it very clear that every industry, every vertical, and nearly every aspect of humanity will be impacted. 5G is being considered a “general purpose technology” or “GPT” like the wheel, steam power, electricity, the computer, and the Internet. All carriers have the ability to thrive, however are likely to have to play “up the stack” in order to do so otherwise will be relegated to monetizing 5G via simple access/connectivity, which is likely to represent only a small fraction of the 5G TAM opportunity. While the carriers admittedly have a poor track record of doing this, with 5G somebody will need to make sense of all the data, and carriers sit in an advantageous position. Each carrier will play to their respective strengths and choose their own adventure.

IoT Represents the Biggest 5G Opportunity for the Carriers

Perhaps the most under-appreciated opportunity is IoT, especially when combined with blockchain data management and artificial intelligence (AI) computing. By 2025, GSMA expects global IoT to be a $1.1T rev. opportunity (from $267B in 2018). However, only 5% of total IoT revenue will be driven by connectivity while 68% will be driven by applications, platforms, and services, and the remaining 27% by professional services. To our earlier point, in order for carriers to expand their TAM, each carrier will have to select subset/industry IoT opportunities where they can play “up the stack” and provide a full solution set. For example, Verizon has already made several acquisitions to play within the fleet management and connected city opportunities.

CTO’s Talk Their Respective 5G Strengths; Verizon FWBB Appears Limited for Now; New iPhone eSIM and Single SKU are Notable Changes

Each Big 4 CTO played to their respective strength, with AT&T highlighting fiber and media ownership/distribution, Sprint the power of AI and leveraging the SoftBank “Curiosity” platform, T-Mobile on its 600 MHz and merger with Sprint, and Verizon on its fiber and first-mover advantage with fixed wireless broadband. We find the “Verizon 5G Home” should have a muted impact given the required truck roll and 300 Mbps speed, at least initially. Separately, the Apple device launch is interesting in that a single SKU now supports eSIM and all relevant US bands across carriers, which could facilitate the ability for BYOD and switching, although we believe it is unlikely that carriers will be willing to buy out the balance of EIP plans beyond the typical promotions offered today. If we do see an uptick in industry churn, we believe this would be beneficial to T-Mobile given its past ability to take advantage during periods of elevated customer switching in the industry.

Please see pages 8 to 13 of this report for important disclosures.
5G/Fixed Wireless Reports

T-Mobile IR Meeting
Cowen VZ/Samsung 5G Panel
VZ Sell-Side Event
5G Presentation

5G: The General Purpose Technology

REPORT
We’ve heard about the “game-changing” capabilities of 5G many times before and this excitement/narrative was at a fever pitch at the conference. With Release 15 now approved and 5G fixed wireless now underway, the commonly referenced 5G use cases (i.e. Fixed Wireless, Autonomous Vehicles, “remote surgery”, etc.) seemed stale/narrow minded as various panels and floor exhibits showed the perspicuous and profound nature of 5G, making it very clear that every industry, every vertical, and nearly every aspect of humanity will be impacted. To that point, 5G is being considered a “general purpose technology” or “GPT” like the wheel, steam power, electricity, the computer, and the Internet. Perhaps most under-appreciated is 5G’s transformational impacts via the enablement of IoT, and in doing so will be combined with blockchain data integrity/management (see blockchain section below) and artificial intelligence (AI) computing, for life-changing and society-changing impacts. AI is finally becoming reality, driven by advancements in chipsets, distributed computing (with a supercomputer in your pocket, on the mobile edge, or in the cloud), but AI needs data. As such, IoT, and its billions of devices, across essentially every vertical, will provide that data. With 5G allowing “everything as a service” or “XaaS”, the Big 4 U.S. carriers (and possible new carriers) have the ability to thrive, however are likely to have to play “up the stack” in order to do so otherwise will be relegated to monetizing 5G via simple access/connectivity, which is likely to represent only a small fraction of the 5G TAM opportunity (despite the billions of connections). While the carriers admittedly have a poor track record of doing this, with 5G somebody will need to make sense of all the data, and carriers sit in an advantageous position of accessing, securing, transporting, and gathering said data. With that said, the 5G opportunity set is likely to be too expansive to hone in on all use case targets, thus each carrier will play to their respective strengths and choose their own adventure.

IoT Represents the Biggest 5G Opportunity for the Carriers

The enablement of the upcoming IoT revolution is perhaps the most interesting pillar of 5G and will leverage the two other pillars including enhanced mobile broadband and ultra-low latency. By 2025, GSMA expects global IoT to be a $1.1T revenue opportunity (313% growth from $267B in 2018). Despite the expected 25B connections though, only 5% of the revenue will be driven by connectivity while 68% will be driven by applications, platforms, and services (analytics, security, cloud storage), and the remaining 27% by professional services (integration, consulting). In the past, we’ve categorized IoT into three general application categories: in-home IoT, narrow-band IoT (NB-IoT), and broadband IoT (BB-IoT). However, a different way of thinking about segmenting IoT is by the type of connectivity. We can again think about IoT in three buckets: 1) short-range IoT, 2) long-ranged unlicensed IoT, and 3) long-ranged licensed IoT. While carriers should dominate the long-ranged licensed IoT connectivity opportunity, it will be interesting to see how the carriers play in the unlicensed buckets, leveraging existing residential and enterprise relationships, while we also think about cable’s foray into the in-home (unlicensed) space. The size of the connectivity opportunity will depend on the application and device. Breaking this down further, connectivity type will depend on: 1) packet size; 2) type of network (topology); 3) power consumption; and 4) the desire for vendor neutrality (is vendor lock-in a deal-breaker or not). In addition, in order to expand their TAM, each carrier will have to select subset/industry IoT opportunities where they can play “up the stack” and provide a full solution set. For example, Verizon has already made several acquisitions to play within the fleet management and connected city opportunities.
Blockchain: An Emerging Topic in Telco and 5G

In the past we’ve largely associated blockchain technology as a crypto-currency solution. However, blockchain can and will be leveraged by enterprises and smart cities, and subsequently is an emerging topic in the telco space over the past few months (including a presentation at our August Cowen Communications Infrastructure Summit). To that point, blockchain was prevalent at MWC Americas. For example, today enterprises store, own, manage, and analyze data in isolated silo’d databases (either on prem, off prem, or in a private/public/hybrid cloud environment). The data is difficult to share across other enterprises (or third-party aggregation players such as governments), can become less reliable if more parties are allowed to modify/change the data records, can be difficult to compare with disparate data across other data sets, and can thereby lack security, integrity, and usefulness. However, with blockchain, a multitude of enterprises/entities can access or input data into a single shared database. No party can modify the data without permission from all other parties. For example, Garmin can populate traffic data into a database (coupled with your personal bio data when you registered your Garmin device) that can correspondingly be linked with hospital data, carrier data, city construction data, city traffic data (parking, traffic lights), with all parties working together sharing a single data depository. Blockchain allows disparate data from multiple sources to be centralized into one depository ensuring integrity and reliability (as the data is certified by all parties). This “one stop shop” allows for unparalleled big data analytics and AI opportunities. With this oversimplified illustration, one can see the value of block chain when combined with IoT sensors/monitors and big data analysis. IoT measures, blockchain stores, and AI analyzes. For more information on blockchain, please see Cowen’s blockchain Ahead of the Curve report, “Blockchain: Beyond Bitcoin, the Enterprise Evolution” published on May 24, 2018.

Takeaways from Big 4 CTO 5G Interviews

AT&T - Andre Fuetsch - President AT&T Labs and CTO. All carriers agree that the true definition of 5G is “a new radio interface”, though AT&T sees it as an entirely new experience with new engagement models. Feeding off the Time Warner merger, AT&T’s approach is about content, creation, and distribution to all endpoints. 5G is also about the core and SDN (which allows for network slicing, and the subsequent multitude of use cases over the same network and access points), as the carrier reminds us it is the leader in network virtualization. AT&T will launch 5G in 19 markets (12 markets by YE18). The carrier also announced it will trial CBRS 3.5 GHz with a commercial launch in late 2019 (first on LTE then migrate to 5G). Everything AT&T is developing is standards based, and the carrier promotes and supports open based 5G in order to enable new experiences and models. Being closer to the developer community with open platforms is cheaper, quicker, helps AT&T differentiate, and allows for flexibility. AT&T also believes it differentiates with fiber, touting 9MM FTTP locations, and with WarnerMedia. For AT&T, 5G will start with mmWave, including its initial “puck” device that is also compatible with LTE (when outside a 5G zone), then move to sub-6 GHz spectrum (every radio it deploys is 5G ready), with smartphones in 2019 and more devices, chips, and interfaces thereafter. The carrier announced a NB-IoT network for 2Q19.

Sprint - John Saw - CTO. Dr. Saw noted that 5G “will transform every life on the planet”. He sees 5G as a technology that 1) evokes much higher bandwidth, 2) rides on a virtualized, API-driven core network (for network slicing), and 3) disrupts all verticals. Sprint’s 5G stresses the more ambitious transformational visions such as AI. Dr. Saw
highlights Sprint’s ties with SoftBank, a company poised to dominate 5G by owning companies across the platform. Sprint/SoftBank’s newly announced “Curiosity” platform includes subsidiaries such as ARM (chips, security), Packet (edge computing), Nauto (AV), and CloudMinds (AI). Sprint continues to roll out its 2.5 GHz spectrum (on two-thirds of its sites today) and massive-MIMO which will “bridge the gap to 5G”. Massive-MIMO “split mode” has the ability to connect to both 5G and LTE (60 MHz on LTE and 60 MHz on 5G). The carrier continues to heavily deploy small cells and Magic Boxes, eventually deploying 1MM Magic Boxes across the country (250K today). It’s worth noting the Magic Box ease of deployment as simple “plug and play” using 2.5 GHz backhaul. The carrier is less focused on CBRS and unlicensed spectrum as Sprint is already in a solid position with “mid-band” 2.5 GHz spectrum. The carrier expects to have 5G devices in 1H19.

T-Mobile - Neville Ray - CTO. T-Mobile sees 5G as a new radio interface that will migrate through an arch of use cases that begins with a fixed broadband displacement, then to mobile, then massive IoT. The carrier will launch 5G in 30 cities next year (on its 600 MHz and mmWave bands) and expects most of its LTE to be upgraded to 5G five years from now. The carrier is excited for IoT capabilities and smartphone speed on its clean 600 spectrum, and sees value in mmWave in outdoor hotspots (as opposed to FWBB). The company also announced a more expansive deal with Crown Castle for small cell deployment and FTTT backhaul deals with 52 providers by re-contracting scalable agreements that ensure the network is 5G ready. Like the other carriers, it expects to have devices available in 2019, but seemed more tempered on near term expectations reminding us that “not much happened” in the first two years of LTE. The carrier admitted that “we are all struggling on getting mid-band” except for Sprint. To that point the carrier continued to lobby for the merger with its pitch of job creation, a fixed wireless replacement, and accelerate 5G in the U.S. To that last point and on a separate note, last week media reports noted that China may allow its #2 and #3 mobile players (China Unicom and China Telecom) to merge, essentially creating a marketplace of just two large players (China Mobile would be the other). The proposal is to ensure China’s leadership in the 5G space and in our view is likely to help strengthen T-Mobile’s merger pitch to regulators that consolidation is necessary to ensure 5G leadership in the U.S.

Verizon - Nicola Palmer - Chief Network Officer. Verizon talked up its strong fiber portfolio and noted “5G is here, we don’t need to talk about it anymore” as the carrier is open for sale on 5G fixed wireless broadband in its four markets, including a 5G node at the conference convention center. The carrier continued to tout the performance of mmWave propagation after rigorous testing during field trials (a topic Samsung also supported at the conference and at our Cowen TMT Conference). As for the offer itself, “Verizon 5G Home” also announced last week, leaves a bit to be desired, and should have very minimal impact on cable, but should improve over time. Verizon will offer the product at $70/month, or $50/month for wireless customers (includes taxes and fees). It will also offer a free Apple TV CPE, Google Chromecast CPE, or three free months of YouTube TV. However, the offer requires a truck roll (at least initially), is built on its proprietary TF standards (eventually requiring an equipment changeout), and while peak speeds call for 1 Gbps throughput, customers should expect typical speeds of 300 Mbps. We note that in the more dense markets where Verizon will offer “5G Home”, most cable MSOs have either completed its DOCSIS 3.1 rollout or will have done so by YE (which allows for 1 Gbps speeds and a path to 10 Gbps). Thus, outside of an attractive price for Verizon Wireless customers, we believe it will be difficult to make inroads, especially as demand-rich applications (8KTV, AR/VR, gaming) gain traction in the years ahead.
Apple iPhone Announcement - eSIM and single SKU are Notable Changes

Also last week, Apple introduced its latest device and wearables lineup (see details below). All three phone devices will support Band 71 (600 MHz) and Band 14 (FirstNet), GSM, and CDMA (detailed support specs linked here). The XS and XS Max will support 4X4 MIMO and LAA while the cheaper Xr device will not (only 2x2 MIMO). Most importantly, a single device SKU will support eSIM and all relevant bands from the U.S. carriers. This will significantly facilitate the ability for BYOD and switching among all four carriers, although we believe it is unlikely that carriers will be willing to buy out the remaining balance on competitors’ EIP plans beyond the typical promotions that are being offered today (usually upwards of a few hundred dollars). As such, while the technological enhancements are likely to make switching easier, the financial burden of the device itself is likely to govern the true impact. Perhaps more likely is that customers will be more prone to hold onto their own devices even if switching carriers, which may further reduce handset sales (a trend that has already been growing since the introduction of EIPs). To the extent we do see an uptick in industry churn, we believe this would be incrementally beneficial to T-Mobile considering its historical ability to take advantage during periods of elevated customer switching in the industry.

Apple Product Launch Details

iPhone Xs (5.8-inch OLED display)

- **Availability**: Available for pre-order on September 14 and available in stores on September 21.
- **Pricing**: The phone will sell for **$999** for the 64GB model, **$1,149** for the 256GB model, and **$1,349** for the 512GB model. This is the same pricing as the iPhone X which previously was $999 for 64GB model, and $1,149 for the 256GB model. The phone can be paid for in monthly installments on the carrier’s EIP program or the Apple Upgrade Program.
- **Features**: Notable new features include 1) 5.8-inch super retina custom OLED display, 2) A12 Bionic processor (up to 15% faster than A11 and up to 50% lower power usage than A11), 3) 12MP Dual-camera system, 4) Battery lasts up to 30 minutes longer than the iPhone X, and 5) Dual SIM: nano-SIM and eSIM.

iPhone Xs Max (6.5-inch OLED display)

- **Availability**: Available for pre-order on September 14 and available in stores on September 21.
- **Pricing**: The phone will sell for **$1,099** for the 64GB model, **$1,249** for the 256GB model, and **$1,449** for the 512GB model. The phone can be paid for in monthly installments on the carrier’s EIP program or the Apple Upgrade Program.
- **Features**: Notable new features include 1) 6.5-inch super retina custom OLED display, 2) A12 Bionic processor (up to 15% faster than A11 and up to 50% lower power usage than A11), 3) 12MP Dual-camera system, 4) Battery lasts up to 1.5 hours longer than iPhone X, and 5) Dual SIM: nano-SIM and eSIM.

iPhone Xr (6.1-inch LCD display)

- **Availability**: Available for pre-order on October 19 and available in stores on October 26.
Pricing: The phone will sell for $749 for the 64GB model, $799 for the 128GB model, and $899 for the 256GB model. The phone can be paid for in monthly installments on the carrier’s EIP program or the Apple Upgrade Program.

Features: Notable new features include 1) 6.1-inch LCD display, 2) A12 Bionic processor (up to 15% faster than A11 and up to 50% lower power usage than A11), 3) 12MP camera, 4) Battery lasts up to 1.5 hours longer than iPhone 8 Plus, and 5) Dual SIM: nano-SIM and eSIM.

Legacy iPhone Models

- Discontinued the iPhone X, iPhone SE, and iPhone 6s
- iPhone 8 (4.7-inch display) is now starting at $599 for the 64GB model (previously was $699)
- iPhone 8 Plus (5.5-inch display) is now starting at $699 for the 64GB model (previously was $799)
- iPhone 7 (4.7-inch display) is now starting at $449 for the 32GB model (previously was $549)
- iPhone 7 Plus (5.5-inch display) is now starting at $569 for the 32GB model (previously was $669)

Apple Watch Series 4

- Availability: The Apple Watch Series 4 will be available for pre-order on September 14 and in stores on September 21.
- Pricing: The 40mm watch costs $499 for LTE capability or $399 without. The 44mm watch costs $529 for LTE capability or $429 without. The LTE-enabled watch can attach to a subscriber’s carrier plan, although the cost varies by carrier.
- Features: Notable new features include 1) 64-bit dual-core S4 processor (up to 2x faster than S3 processor), 2) Electrical heart sensor (ECG app coming later this year), 3) Fall detection, 4) 40 & 44mm case (vs. 38 & 42mm case for Apple Watch Series 3), and 5) Bluetooth 5.0.

iOS 12

- iOS 12 will be available for download starting on September 17th.
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<table>
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<tr>
<th>Ticker</th>
<th>Rating</th>
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<th>Price Target</th>
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<tr>
<td>S</td>
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<td>$4.90</td>
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<tr>
<td>VZ</td>
<td>Market Perform</td>
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<td>$56.00</td>
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*As of 09/14/2018

VALUATION METHODOLOGY AND RISKS

Valuation Methodology

Telecom Services:

Our valuation methodology consists of an absolute and relative value approach. We arrive at a fair value utilizing a five-year discounted cash flow (DCF) and when appropriate a segmented sum-of-parts (SOP) analysis. Our relative value approach takes into account EV/EBITDA, P/FCF, and P/E and, when applicable, P/AFFO and dividend yield.

Investment Risks

Telecom Services:

Risks Include: (1) many companies within Telecom Services are highly regulated where a change in rules could lead to unfavorable conditions; (2) rapidly changing/disruptive technology, new product/service offerings, and evolving industry/technology standards could have an impact on demand and/or pricing; and (3) deterioration in the macro environment both domestically and internationally could lead to a reduction in demand and a consequent impact on valuation multiples.
**Stocks Mentioned In Important Disclosures**

<table>
<thead>
<tr>
<th>Ticker</th>
<th>Company Name</th>
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<tbody>
<tr>
<td>T</td>
<td>AT&amp;T</td>
</tr>
<tr>
<td>S</td>
<td>Sprint Corp.</td>
</tr>
<tr>
<td>TMUS</td>
<td>T-Mobile US</td>
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<tr>
<td>VZ</td>
<td>Verizon Communications</td>
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The recommendation contained in this report was produced at September 16, 2018, 20:10 ET. and disseminated at September 17, 2018, 05:00 ET.

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Underperform (3): Stock is expected to achieve a total negative return of at least 10% over the next 12 months

Assumption: The expected total return calculation includes anticipated dividend yield

Cowen and Company Equity Research Rating Distribution

| Distribution of Ratings/Investment Banking Services (IB) as of 07/02/18 |
|-----------------------------------------------------------|---------------------|---------------------|---------------------|---------------------|
| Rating          | Count | Ratings Distribution | Count | IB Services/Past 12 Months | Count |
| Buy (a)         | 476   | 63.55%               | 113   | 23.79%                        |
| Hold (b)        | 266   | 35.51%               | 18    | 6.74%                          |
| Sell (c)        | 7     | 0.93%                | 0     | 0.00%                          |

(a) Corresponds to “Outperform” rated stocks as defined in Cowen and Company, LLC’s equity research rating definitions. (b) Corresponds to “Market Perform” as defined in Cowen and Company, LLC’s equity research ratings definitions. (c) Corresponds to “Underperform” as defined in Cowen and Company, LLC’s equity research ratings definitions. Cowen and Company Equity Research Rating Distribution Table does not include any company for which the equity research rating is currently suspended or any debt security followed by Cowen Credit Research and Trading.

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AT&T Rating History as of 09/14/2018

powered by: BlueMatrix

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<th>Count</th>
<th>Ratings Distribution</th>
<th>Count</th>
<th>IB Services/Past 12 Months</th>
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<td>07/25/18</td>
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(1): Corresponds to “Outperform” rated stocks as defined in Cowen and Company, LLC’s equity research rating definitions. (2) Corresponds to “Market Perform” as defined in Cowen and Company, LLC’s equity research ratings definitions. (3) Corresponds to “Underperform” as defined in Cowen and Company, LLC’s equity research ratings definitions. Cowen and Company Equity Research Rating Distribution Table does not include any company for which the equity research rating is currently suspended or any debt security followed by Cowen Credit Research and Trading.

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Legend for Price Chart:
I = Initiation | 1 = Outperform | 2 = Market Perform | 3 = Underperform | UR = Price Target Under Review | T = Terminated Coverage | $xx = Price Target | NA = Not Available | S = Suspended
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