IHS TECHNOLOGY WHITE PAPER

C-SON Rage Against the Machine

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23 September 2016

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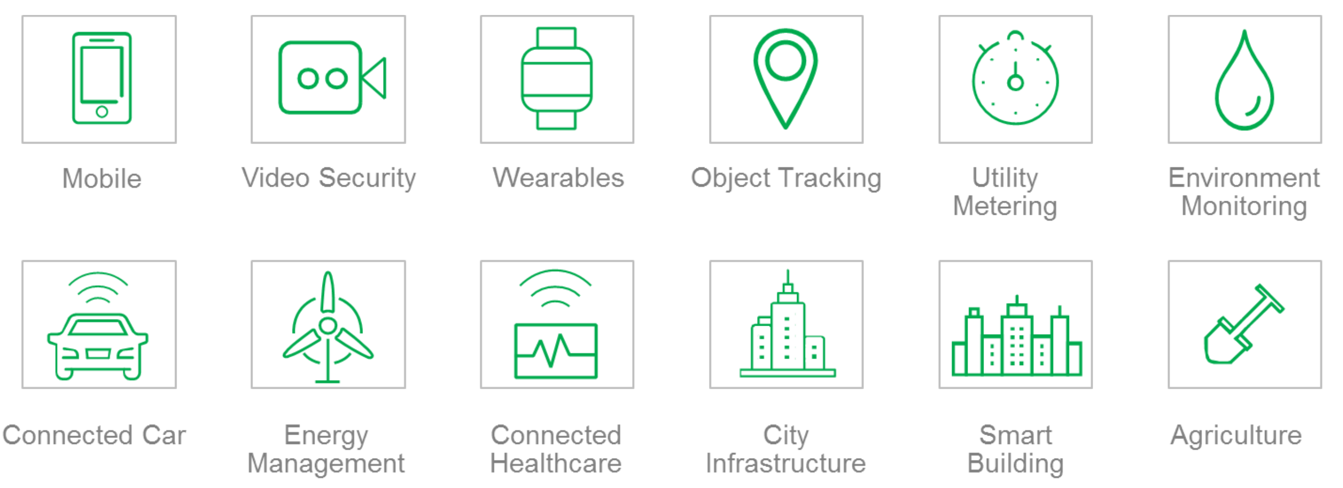
Introduction

Alluding to the famous Los Angeles alternative metal band known for its leftist and revolutionary political views, Rage Against the Machine, our connected world is undergoing a major transformation that requires specific tools to ensure the smoothest transition possible to a world characterized by connected things and more and more machines overtaking the humans. This is commonly known as MTC (machine type communications), communication that involves little or no human interaction and has different requirements than human type communication. However, the transformation seems to be more evolutionary than revolutionary so far, despite the MTC and M2M (machine-to-machine) onslaught on cellular networks—IHS estimates the Internet of things (IoT) installed base at 17.7 billion by end of 2016, of which 284M are cellular M2M connections only.

On one hand, mobile subscriptions have reached saturation and there are as many subscriptions as humans on this planet at around 7.4 billion, although this does not mean everyone has a mobile device. On the other hand, the mobile industry is pulling in a flurry of previously unconnected or under-connected industries ranging from manufacturing, farming, automotive, and home entertainment to city planning and public safety, all grouped under the IoT umbrella, replacing the old fashioned M2M terminology.

Exhibit 1 IoT Use Cases



Source: IHS

As our wireless and cellular networks were not originally designed to handle this transformation, this paper explores how some existing features of centralized self-organizing networks (C-SON) software defined and designed by standards body 3GPP (3rd Generation Partnership Project) in the context of LTE is perfectly suited for the task.

This paper starts with an analysis of the very first thing any cellular network has to provide and guarantee 24 hours a day and 365 days a year: coverage. Cellular operators have been dealing with issues related to poor coverage since the launch of the very first cellular networks in the early 1990s. However, humans were the only users, and predominance of smartphones added new pressure on top of coverage: capacity. In the meantime, a nascent M2M business, mainly narrowband and therefore on 2G, started to flourish, which prompted cellular operators to revisit their coverage and explore new optimization and management techniques such as C-SON CCO (coverage and capacity optimization).

Exhibit 2 provides a list of SON features we expect will play a great role in managing and optimizing IoT networks.

Exhibit 2 SON Features for IoT Networks

Abbreviation	Description
CCO	Coverage and capacity optimization
RO	Random access channel optimization
MLB	Mobility load balancing
PCI	Physical cell identity optimization

Source: IHS

The CCO analysis leads to an overview of the complexity that keeps mounting with the addition of new generation "G" every 10 years along with a vast variety of features blended with LTE. The paper examines how C-SON features can address specific IoT issues such as massive signaling, and it ends with a look at how C-SON can enable adaptive QoS to address the diversity of IoT applications.

C-SON Provides Solid IoT Coverage and Capacity Optimization (CCO)

Coverage is the very first thing any cellular network needs to provide and guarantee. In 2011, the 3GPP released its SON specifications that optimize coverage and capacity through the implementation of 2 algorithms:

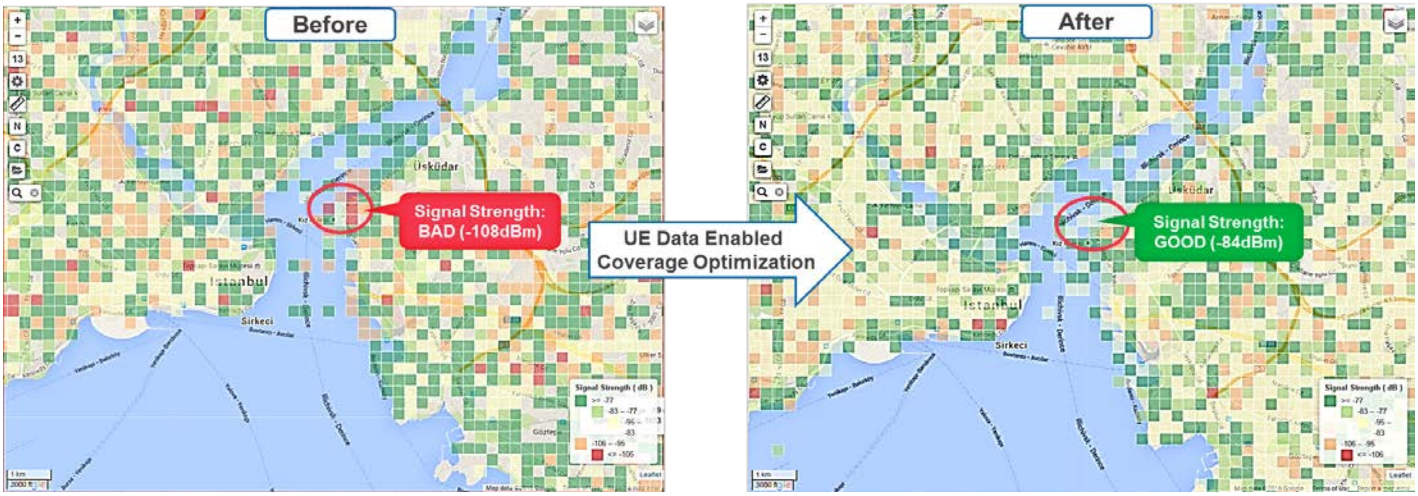
- **CCO Monitor Function** monitors the optimization of capacity and coverage (e.g., monitoring related performance counters, user equipment (UE)/device measurements, or alarms)
- **CCO Policy Control Function** configures the capacity and coverage optimization policies

Those SON CCO algorithms optimize the 3 following parameters:

- Downlink transmit power
- Antenna tilt
- Antenna azimuth

Exhibit 3 provides an illustration of coverage optimization performed by a C-SON optimizer that uses inputs coming from an application installed on the UE. The left side shows red spots representing bad coverage that are reported to C-SON, which in turn activates CCO algorithms to restore an optimal coverage, represented by red spots turning green in the right side. C-SON coverage optimizer correlates different inputs from network, including but not limited to performance counters, call-trace/MDT logs, third-party crowdsourcing data metrics, CEM/probes to capture RF environment, and user experience high-end equipment.

Exhibit 3 C-SON CCO in Action



Source: P.I. Works

Seamless coverage is crucial to ensure a reliable connection to any cellular network

For the past 2 decades or so, the mobile industry has relentlessly worked to address poor coverage issues. Without seamless coverage, there is no capacity, which was not a concern during the 2G voice era but became a significant one after the launch of the first iPhone in June 2007. Today, with smartphone penetration way above 50% and the rise of IoT with more and more sensors, diverse things, and machinery connected to those same cellular networks, coverage and capacity work in tandem. 5 typical symptoms of CCO-related issues include:

- **Weak coverage** occurs when the pilot signal strength or the signal-to-noise ratio (SNR) or signal-to-noise-plus-interference ratio (SINR) of the serving cell is below the level needed to maintain a planned performance requirement such as cell edge bit-rate.

- **Coverage hole** is probably the most frequent type of coverage issue cellular operators are facing today in their macrocellular networks. Each base station (e.g., BTS in 2G, NodeB in 3G and eNodeB in 4G) is set to cover a specific area. However, physical obstructions such as buildings, hills, or unsuitable antenna parameters, and just inadequate RF planning may alter the strength of the pilot signal, which can go lower than the threshold required by a cellular device—user equipment (UE)—to access the network. When this happens, the radio link will fail and the connection will drop.

- **Pilot pollution** defines an area where several pilot signals coming from various base stations overlap and create a high level of interference. As a result, the UE will receive high SNR from multiple cells, creating an unstable connection.

- **Overshoot coverage** refers to the pilot signal reaching out to beyond its planned area and resulting in islands of unintended coverage in other areas that may not be set as direct neighbors.

- **DL and UL coverage mismatch** occurs when the downlink (DL) channel coverage is larger than the uplink (UL) channel, which will create UL issues when the UE is in this area.

Always-on coverage is absolutely required for IoT

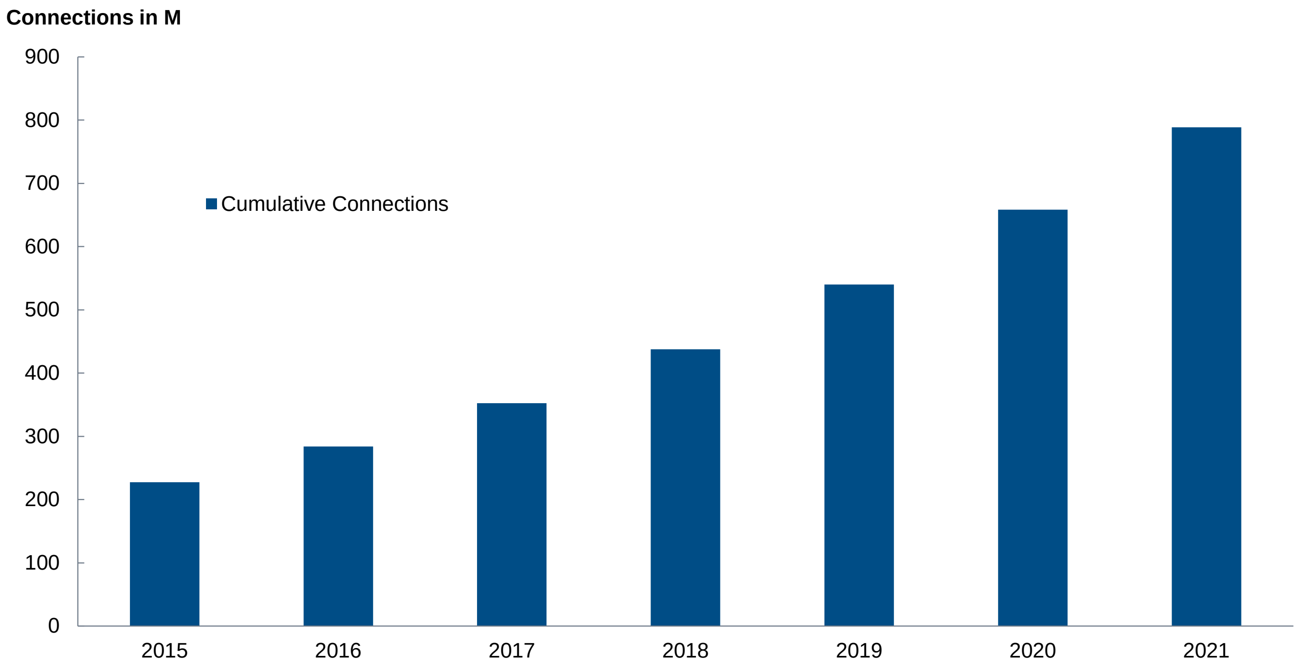
Network availability is undeniably the most important parameter for any cellular IoT system. New systems (e.g., NB-IOT) are being designed to provide better coverage, especially for better indoor penetration. Existing C-SON CCO described above already enhances indoor coverage, providing better access for IoT applications.

More broadly, critical applications ranging from narrowband industrial monitoring to remote robotic surgery cannot afford a dropped connection; they need to remain connected to the cellular network throughout the duration of their task. For example, monitoring chronically ill patients via wearables is a common case that requires always-on indoor coverage.

Only C-SON Will Manage Massive IoT Cellular Connections

IHS predicts that the number of M2M cellular connections will grow from 283.9M in 2016 to 788.8M by 2021 at a CAGR of 23% (see Exhibit 4). Consequently, the number of challenges is mounting proportionally, outpacing humans' abilities to deal with them and reinforcing the need for more software and automation solutions. Three of the most important challenges can be addressed by C-SON: signaling, bandwidth, and power consumption.

Exhibit 4 Cumulative Cellular M2M Connections Worldwide



Source: IHS, June 2016

C-SON MLB will handle signaling and bandwidth issues

When Apple launched its first iPhone 3G in 2007, AT&T learned the hard way that its cellular network was unready to cope with the signaling storm that emerging chatty applications triggered. Throwing more RNCs in its W-CDMA/HSPA network was the initial response, followed by a fast migration to LTE. In parallel, C-SON started to be deployed to handle these types of signaling challenges.

Connected IoT devices have the potential to replicate the iPhone experience. To play their assigned role, these IoT devices require reliable bidirectional signaling for collecting and routing data between them. These very different devices may be talking to a server to collect data, or the server may be talking to the devices, or maybe those devices are talking to one another. No matter what the use case, data needs to get from point A to point B frequently and reliably to ensure that the data stream arrives at its final destination every time. That in turn is generating a lot of traffic that needs to be accommodated in crowded cellular networks.

And as licensed cellular spectrum is an expensive, scarce resource, cellular bandwidth is not cheap. Massive numbers of IoT devices sending and requesting responses on those networks will certainly increase the pressure on available bandwidth that is directly related to the capacity. C-SON MLB is the perfect tool to address this issue.

C-SON MLB correlates resource utilizations and cell loads across different bands and technologies to ensure the optimum load distribution necessary for handling gigantic numbers of connected sessions. This will not only reduce the required investment for capacity extensions but also improve the power consumption of mobile devices by reduced interference levels of air interfaces.

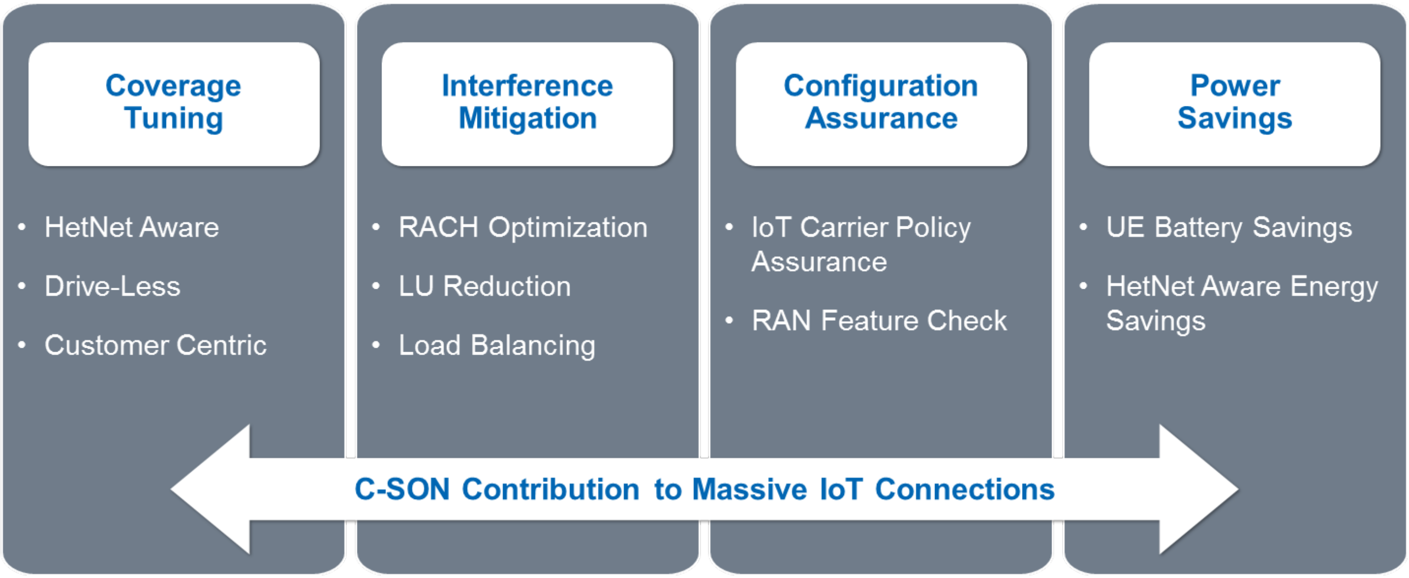
C-SON RO will handle packet collision

The massive increase in number of connections will trigger more packet collisions in the uplink during wireless network access. C-SON RO (random access channel optimization) techniques inherently improve accessibility under heavy load and reduce network access delays due to less retransmission with fewer collisions. In addition, C-SON RO leads to better handover performance for all subscribers as well as IoT devices.

C-SON sets coverage tuning, configuration assurance, and power saving in multi-band, multi-frequency IoT networks

IoT traffic patterns might be diverse with a combination of low volume and very high bursts. This type of pattern will require special coverage layers at low bands. This may eventually lead to extensive frequency re-farming works. In addition, as various cell footprints may use different frequency bands, neighbor optimization, and inter-frequency load balancing actions, running LTE-Advanced features such as carrier aggregation (CA) and coordinate multipoint reception (CoMP) functions will be difficult and require extensive parameter optimization. In the context of brand new IoT services added to the network, mobile operators will be using special RAN features and golden parameter settings for IoT serving carriers that are likely to be different from legacy carriers. C-SON will minimize the potential operational burden associated with this new parameter setting optimization. By collecting configuration parameters and conducting all required correlations in operators' heterogeneous networks to ensure leverage golden settings and complex RAN policies, C-SON can also determine new IoT device aware policies such as golden parameters and layer management.

Exhibit 5 C-SON Contributions for Massive IOT Connections



Source: IHS

C-SON tunes RAN features with hybrid actions to minimize power consumption

Millions of IoT devices sending and receiving streams of data between one another takes a toll on power and CPU consumption. With all this communication, minimal battery drain and low power consumption are no longer valid options. In addition, IoT devices are typically small and cheap and therefore can't afford an expensive embedded CPU power.

C-SON also offers hybrid optimization techniques such as optimum configuration of DRX (discontinuous reception)/paging cycle that will be used to support applications with different latency requirements for application server triggered events. Similarly, C-SON also optimizes vendor's uplink power control algorithms. This results in better IOT equipment battery life while maintaining high accessibility from and to IOT devices.

And C-SON energy saving offers a much broader scope

Correlation capability of centralized energy saving tools allow smart deactivation and activation policies while taking into account the existence of other colocated technology layers, mobility activities between cells, and historical traffic profiles. This not only enhances the user experience by reducing vertical (inter-technology and inter-frequency) mobility activities but also minimizes the risk for low throughput and session drops. On the other hand, UE category-aware carrier deactivation policies on centralized energy-saving features save the battery of wearable IoT devices by keeping low band coverage carrier layers on. It also contributes to effective utilization of throughput, boosting features like CA and dual carrier (DC) by shutting down unused carriers.

Only C-SON, Not Humans, Can Manage this Unabated Network Complexity

Every decade, the mobile industry adds a new generation of mobile networks that incorporates tons of new features. Exhibit 6 provides a simplified illustration of the current situation, showing the evolution from 2000 to 2020.

Although all networks are eventually converging to LTE, the universal platform, new features and options are added at a fast pace in parallel with the existence of 2G and 3G, and the race to 5G is already on. The goal remains unchanged: stay ahead of any capacity crunch while improving efficiencies. This means reduced cost per bit, improved throughput per user, and reduced device connection latency.

C-SON is totally vendor and "G" agnostic

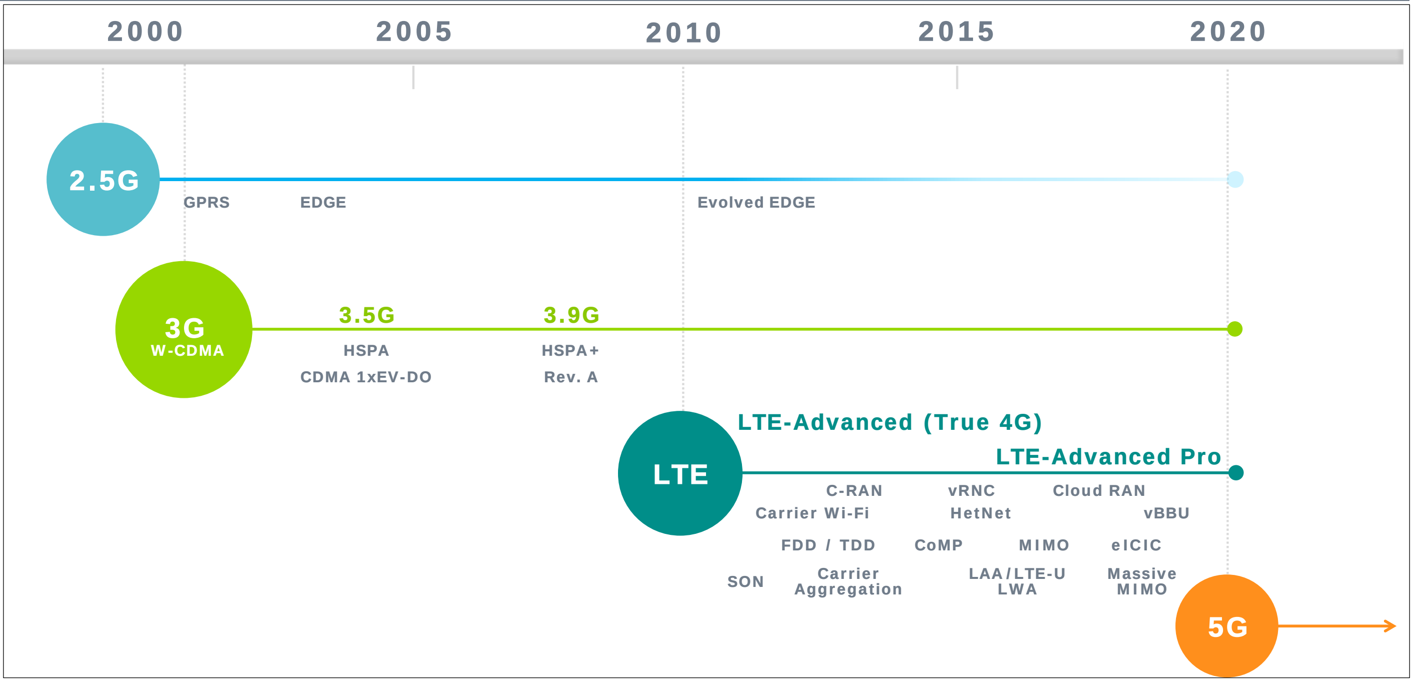
SON, standardized by the 3GPP, started as baked in LTE with functions distributed among the network elements at the edge of the network: the eNodeBs. This implementation is known as distributed SON (D-SON) and is supplied by traditional RAN vendors. As a result, D-SON is generally RAN-centric and proprietary, which created the need for a more centralized SON system to coordinate and manage the accumulation of D-SON islands.

C-SON typically sits at the same level as the OSS and is supplied by a flurry of vendor specialists such as P.I. Works. In parallel with the fast rollout of LTE networks that has now passed its peak—521 commercial LTE networks out of a total of 750+ mobile networks worldwide—C-SON emerged as a powerful optimization and configuration tool for 2G, 3G, and LTE networks.

Some 2G networks have already been shut down (e.g., Japan, Korea) and others are imminent (e.g., Australia, Brazil, Singapore, Thailand, and AT&T in the US), but the planet remains covered by a vast majority of GSM networks that may not disappear anytime soon, even less so when a lucrative M2M or IoT business is kept alive. Nonetheless, 2G networks still support the bulk of existing IoT connections and the move to a next generation is slowed down by embedded modems that cannot be easily changed. In addition, many IoT use cases do not require the performance offered by LTE networks, but the growing diversity of IoT use cases, such as real time robotic surgery and chronic disease monitoring for example, is driving the need for a brand new 5G network. Although pre-standard, pre-commercial 5G deployments are expected as soon as 2017 in the US, followed by South Korea in 2018 in time for the Pyeongchang Olympics, the 5G standard is planned to be ready in 2020 with early commercial rollouts to follow immediately, starting in Japan for the Tokyo Olympics.

Conventional wisdom leads to the expectation that cellular IoT technology should be at least deployable on existing radio access sites. The re-use of existing equipment, such as antennas and feeder cables, brings many challenges for wireless operators in terms of managing a radio network where the same site/antenna will also be shared with other applications such as VoLTE and mobile broadband or possibly enhanced mobile broadband in the 5G environment. When introducing a new generation of standards or a new set of features in the network, the objective is always interworking and backward compatibility. And ongoing 5G developments point in that direction as well. In fact, IoT industrial use cases in addition to consumer use cases will be the chief driver for 5G.

Exhibit 6 Network Complexity



Source: IHS

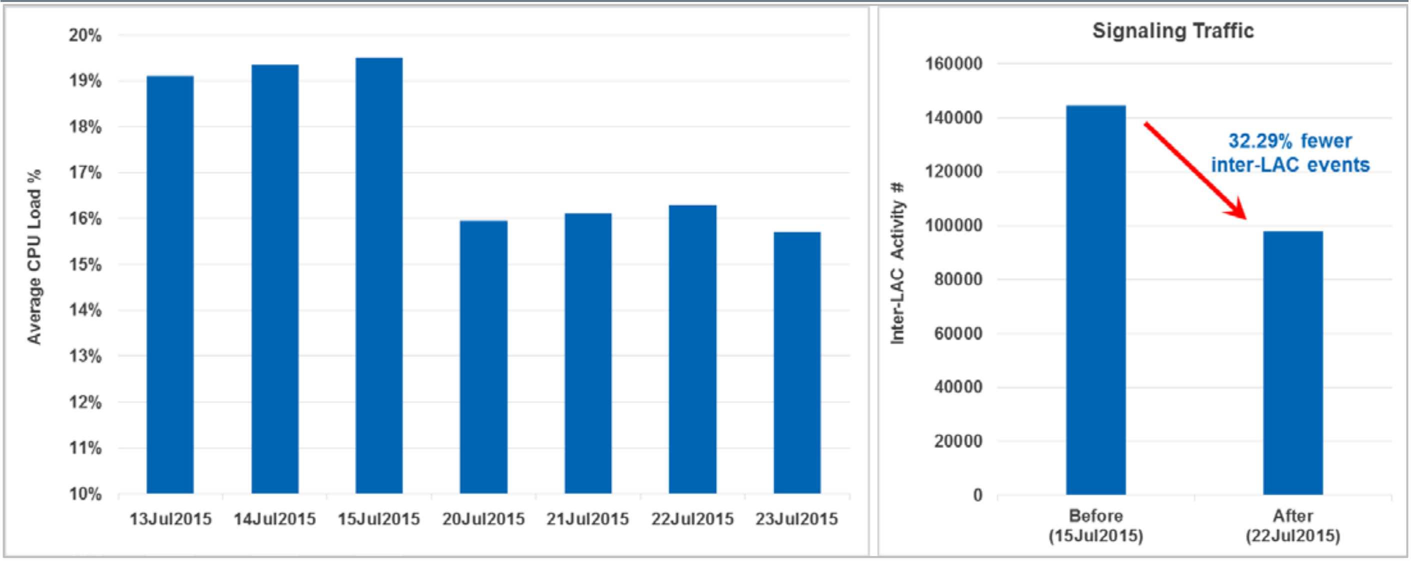
In this complexity, C-SON thrives, particularly in multi-technology multi-vendor environments

As illustrated in Exhibit 6, the LTE/4G era provides a full quiver of ammunition to cope with the capacity crunch. Mobile network operators are continuously expanding and densifying their network by deploying new architectures such as C-RAN (e.g., centralized, coordinated, cloud RAN), aggregating new carriers (e.g., LTE-Advanced carrier aggregation), adding small-cells, introducing unlicensed spectrum usage (e.g., LTE-U), embracing carrier WiFi and aggregating it with LTE (e.g., LWA), and virtualizing network nodes (e.g., vRNC, vBBU).

Nonetheless, the introduction of all the above technologies is not riskless. Potential signaling explosion (e.g., RACH and paging), cross interface coordination between legacy and NFV/cloud vendors, HetNet mobility, and interference mitigation still pose a threat, and even more so in the IoT context. With traditional OEM vendors introducing new radio networks and distributed SON (D-SON) features like extended coverage-GSM-IoT and NB LTE-M, for example, the need for C-SON to sit on top and manage the entire IoT platform has never been so great.

For example, Exhibit 7 depicts how C-SON minimizes signaling needs in wireless networks, which provides additional gains when massive IoT related signaling events occur. In this particular example, a C-SON location area code (LAC) optimization module, which is also cluster-aware and technology-agnostic, is used in a multi-vendor region of a tier 1 European mobile network operator. The tuned location area codes have decreased the CPU load on network nodes by reducing location update signaling.

Exhibit 7 Impact of LAC Optimization on CPU Load



Source: P.I. Works

Similarly, cell type aware and cross-vendor proof RACH-RSI (root-sequence-index) optimizers allow interference-free HetNet operation through periodically optimized RSI plans. For instance, P.I. Works' HetNet RSI optimizer ensures adaptive RSI separations based on source and target cells coverage ranges, which minimizes possible RACH collisions and allows IoT devices to connect faster.

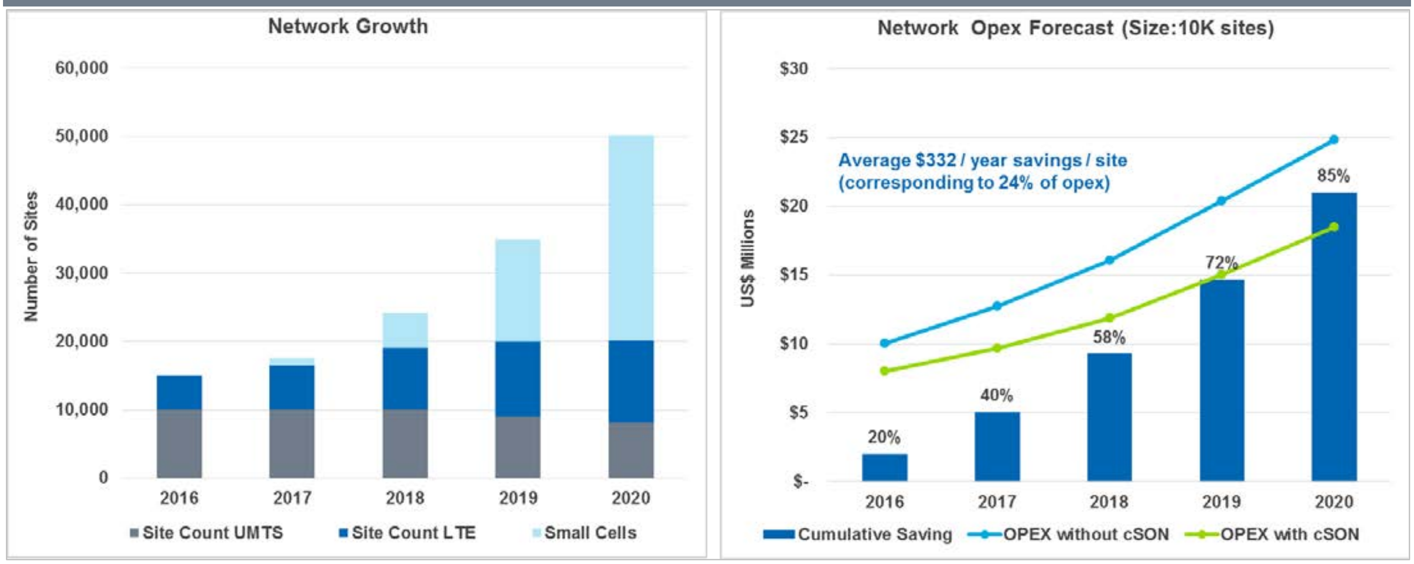
C-SON Will Provide Adaptive QoS as IoT Use Cases Differ and Require Specific SLAs

Cellular IoT applications require specific quality of service components from wireless networks—mission critical apps require specific performances and high levels of service and SLA differentiation. Management of this requirement in coordination with non-IOT cellular traffic is a necessity. As a solution, SON policy tuning functions need to adaptively distribute users of wireless network including IOT users in accordance with instantaneous QoS needs as defined in their IoT SIM cards. Additionally, operator-specific or generic service management platforms shall be an actor in SON policy tuning functions in order to make sure SLAs are in place.

And in the end, C-SON will generate substantial savings

Most IoT devices are expected to be in smart house appliances, vehicles, and wearables. Due to nature of these devices, deep indoor penetration with controlled mobility and the ability to handle huge signaling load is critical. For that reason, special dedicated carriers will be launched, resulting in additional operational costs. Exhibit 8 illustrates the contribution of the C-SON algorithms to radio network planning and optimization under given assumptions, leading to a substantial reduction in operational expenditures (opex). Automation of new site location selection, pre-launch, post-launch, and periodic radio network optimization needs brings 24% opex savings network wide annually (see the assumptions below the chart).

Exhibit 8 Potential Opex Reduction Generated by the Use of C-SON



Source: P.I. Works

Assumptions:

- *3G macrocells: 100 with an average growth ratio of 0.95x*
- *4G macrocells: 5,000 with an average growth ratio of 1.25x*
- *Small cells: 10,000 with an average growth ratio of 5x*
- *First-year operational cost: $10M*

Conclusion

This paper shows that C-SON, already in action in many mobile broadband networks, is poised for playing a major role in self-managing, self-optimizing, and eventually self- healing IoT networks.

C-SON is designed to help operators not only to manage the increasing complexity and maximize the user experience through optimization but also to play a major role in addressing key IoT deployment challenges. As described in this paper, seamless coverage for always on connectivity is the very first thing C-SON CCO will guarantee to enable new IoT opportunities toward 5G.

Once coverage is established and connectivity is on, C-SON MLB will also manage signaling and bandwidth issues, C-SON RO will minimize packet collisions by providing optimum configurations designed for IoT networks, and C-SON will optimize power consumption through RAN feature tuning with hybrid actions.

As C-SON is vendor and G/technology-agnostic, its power of reducing signaling traffic, optimized paging, location update, RACH procedures, and improved efficiency with smart mobility optimization and energy saving functions will keep the machines under control in the IoT age.

All in all, C-SON not only provides great monitoring and control but does so while achieving operational efficiencies estimated at an average annual opex savings of 24% (based on the assumptions noted below Exhibit 8).

Commissioned by P.I. Works to educate the telecommunication industry about the role of C-SON in managing and optimizing massive wireless connectivity dominated by things and machines, this paper was written autonomously by analyst Stéphane Téral based on IHS's independent mobile infrastructure research.

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