THE LTE IMPERATIVE

TECHNOLOGY & MARKET BRIEF

WHITE PAPER

Corporate CTO Group,
Corporate CTO Business Modeling Group
and Bell Labs Enabling Computing Technologies Department

EXECUTIVE SUMMARY

With the proliferation of new smart devices/tablets and the move towards storage, streaming and processing of all apps and content from the Cloud, there is a manifest need to provide 10x or more capacity at approximately the same capital expenditure to maintain constant profitability. Solving this conundrum is at the heart of the operator wireless business strategy for the coming years. In this paper, we present an analysis that quantifies the amount of bandwidth that can be profitably delivered by operators using the different technologies available (e.g., 3G, LTE and small cells). We then use economic game theory to outline the winning strategy for operators and, in particular, the relative merits of an LTE-centric versus Single RAN (mixed 3G and LTE)-centric deployment strategy.

In short, we find that:

- Operators can profitably offer 10x (or more) bandwidth using LTE and small cells technology than they can based on 3G technology.
- The winning strategy for operators is always to deploy an LTE-centric strategy (LTE overlay), including small cells; such a strategy always wins the market competition (game) by delivering maximum capacity at the required profitability.
- Even if an operator has begun deploying a Single RAN strategy, migrating to an LTE overlay strategy as fast as possible will allow it to also win the market in the longer term.
- The only successful Single RAN strategy is one where all operators in a market employ the same strategy and manage the capacity demand so they are able to deliver the demand at the current profitability. However, if a single operator deviates from this ‘common strategy’ at any point and deploys LTE, that operator will immediately disrupt the status quo and win the dominant market share.

We validate these results by comparison with real world market dynamics that are playing out in the wireless marketplace today.

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INTRODUCTION

The proliferation of mobile devices (smartphones, tablets, enabled laptops) and the move towards storage, streaming and processing of all apps and content from the Cloud are creating huge demand for capacity in service provider networks. At the same time, capital expenditure budgets are not growing. As they develop their wireless business strategies for the coming years, operators must determine now how they will address this challenge.

Maintaining the status quo is simply not feasible given anticipated growth. Service providers must choose between building a Single RAN architecture (mixed 3G and LTE), an LTE Overlay or LTE Small Cell architecture. As the analysis below shows, the cost per GB for each of these options is dramatically different. Fortunately, through the application of economic game theory, we are also able to identify the strategy most likely to help operators remain profitable and protect their competitive position.

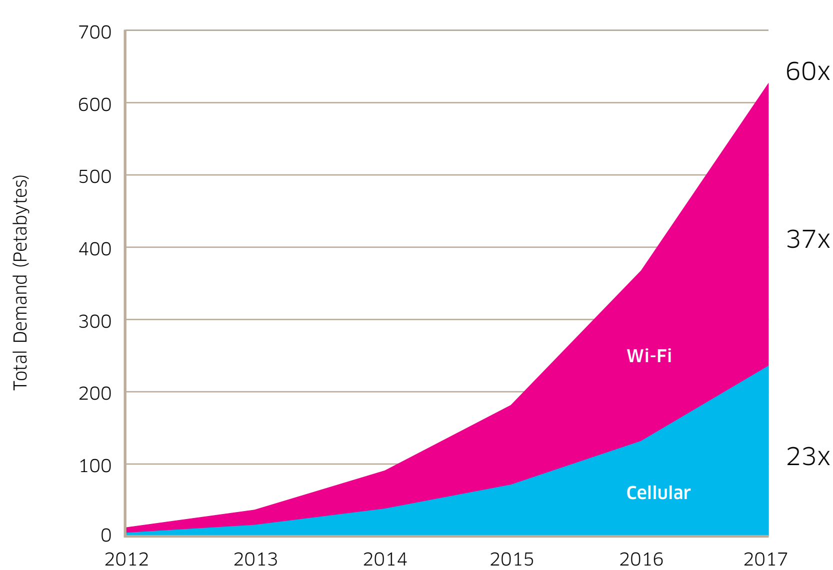
PREDICTING FUTURE DEMAND

Predicting the future demand for mobile broadband is intrinsically risky as opinions vary by two orders of magnitude (ranging from 10 to 1000 times the 2011 bandwidth reference). Furthermore, with the shift from smartphone-dominated usage to increasing tablet usage, past predictions are likely a poor basis for analyzing the future, due to the manifold differences between the two devices, in terms of screen size, applications used, and the duration and persistence of usage.

Therefore we have opted to build a 'bottom up' model of future demand that uses (U.S.) census data about age demographics and the time spent in various locations throughout the day (e.g., home, away from home in a fixed location, in transit, and in the office). We then project an application usage pattern for each of the different demographics as a function of time (of day, and per year) and then average these results to obtain our demand forecast for the coming years. We also apportion the relative fraction of the demand that is satisfied by cellular networks (3G, LTE) or Wi-Fi® networks, based on the location, mobility and QoS requirements.

As shown in Figure 1, we predict that unconstrained user demand for wireless data will grow 60x from 2012 to 2017, and that roughly 2/3 will be served by Wi-Fi (predominantly at home and at work) and 1/3 should be served by cellular networks.

Figure 1. Predicted wireless bandwidth demand from smartphones and tablets in the US through 2017, and the relative contribution of licensed (cellular) and unlicensed (Wi-Fi) technologies in satisfying demand



It is important to recognize that the above analysis only considers the intrinsic demand for bandwidth, but does not take into account the supply side economics. The key question is, therefore: What fraction of this demand can operators profitably satisfy? Clearly, based on the anticipated prominent role of Wi-Fi, a significant amount of this demand can be satisfied at low cost to the operator, assuming that the Wi-Fi service is provided either by end users or their places of work, and using an existing broadband connection. So, we do not consider this portion of the traffic growth in our subsequent analysis, and instead focus on the economics of satisfying the cellular network demand to provide ubiquitous coverage, high mobility and higher QoS services.

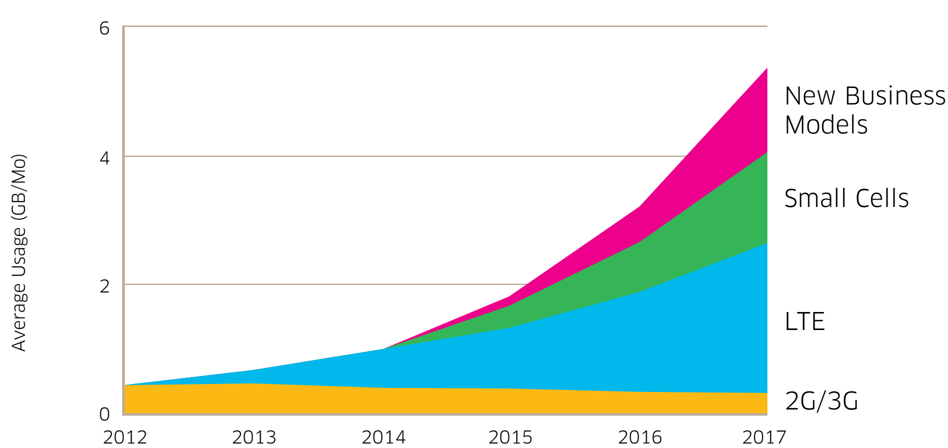
QUANTIFYING PROFITABLE GROWTH

In order to analyze the amount of profitable growth in mobile data that can be accommodated going forward, we have used an equilibrium model that computes the balance point between supply and demand that results in maintenance of the current level of service provider operating profit (~20%). The key change that drives the evolution of the equilibrium is the change in the cost of the infrastructure required to deliver bandwidth, with LTE and Small Cells representing lower cost-per-bit solutions than 2G/3G.

Based on our network modeling, we calculate that with today's 2G/3G infrastructure, an operator's variable cost to provide an incremental GB of capacity is about $30-45[1] (depending on the extent of 3G+ deployed). In contrast, by implementing LTE, an operator can bring this down to about $12/GB and with the introduction of Small Cells this can be reduced to about $9-$10/GB. In addition, if new business models are implemented that allow either lower delivery cost (e.g., by using off-peak capacity) or the generation of additional revenue associated with guaranteed delivery, further profitable growth can be accommodated.

The essential result is shown in Figure 2. We find that by evolving the cellular technology as described above, an operator will be able to increase the amount of data it can profitably provide its customers from about 0.4GB/month with 2G/3G, to 2.5GB/month with LTE and 4GB/month with small cells, or 10 times the previous 2G/3G offer.

Figure 2. Profitable growth in data consumption supported by different technology and business options.



Furthermore, we find that with a more aggressive 4G and Small Cells deployment strategy (~90% of subscribers on LTE by 2017, compared with 35% for the above case), the amount of data an operator can profitably provide will increase by an additional 80%.

1. All monetary values expressed in United States dollars.

From the preceding analysis it would appear that there is a compelling argument for the migration to LTE and Small Cells. However, many operators have employed a so-called 'Single RAN' approach, wherein a mix of 2G/3G and LTE technologies are deployed. Other operators deploy an LTE 'overlay' approach that essentially focuses all growth on LTE, maintaining, but not evolving, the separate 2G/3G networks. So we are interested in exploring the question of how an LTE overlay strategy would compete with a Single RAN strategy in terms of market success. In the next section we explore this question using economic game theory approaches.

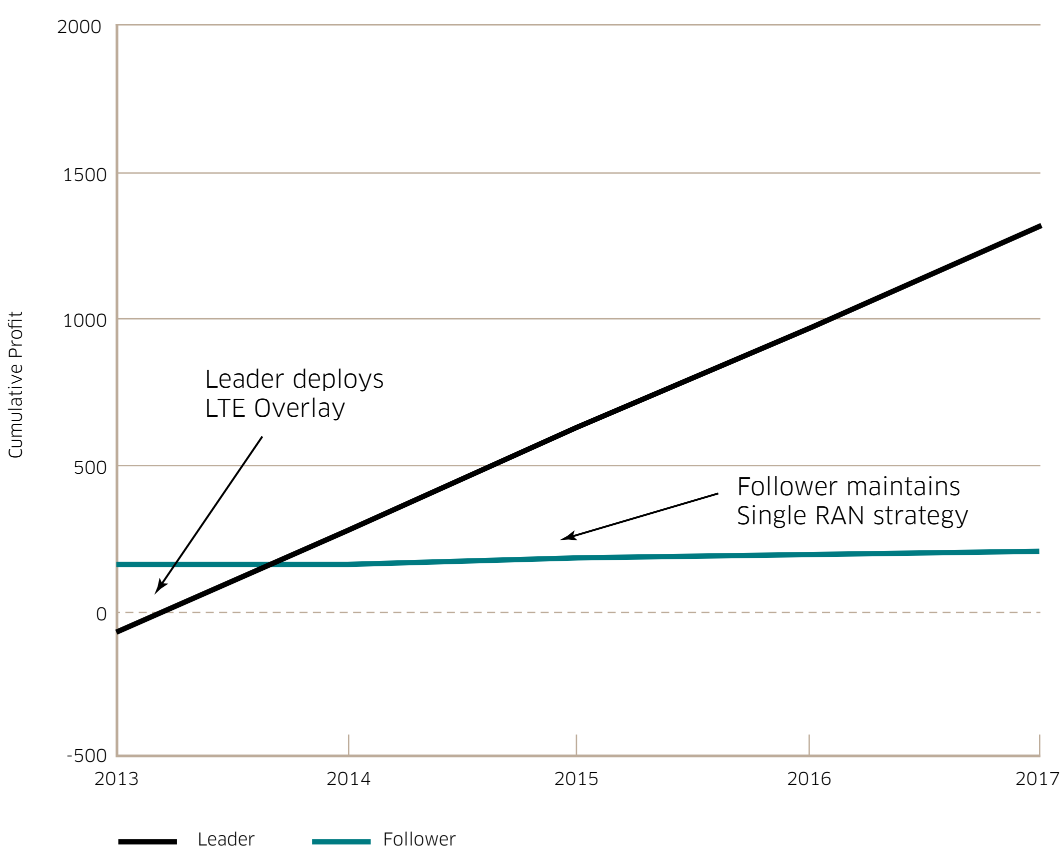
WINNING THE GAME

To investigate the winning strategy for an operator given a choice between Single RAN, LTE and Small Cells approaches to wireless network growth, we have employed a Stackelberg model. The Stackelberg model is a game theoretical framework for exploring the competition between a small number of competing players in a market — in this case, the wireless market.

Within this model, a first mover, called the 'Leader', leverages an inherent advantage (such as technology, geography, regulation, incumbency) to set the quantity (wireless capacity) it can profitably supply to the market. Then the competitors, known as 'Followers', optimize their quantities based upon the quantity set by the Leader. They have two clear choices in terms of approach: either adopt the same approach as the Leader or maintain their current approach, with the attendant different economics.

The outputs from the model are shown in Figures 3 to 5.

Figure 3. Results of the game theory analysis of a competition between operators deploying two different approaches to providing wireless network capacity.

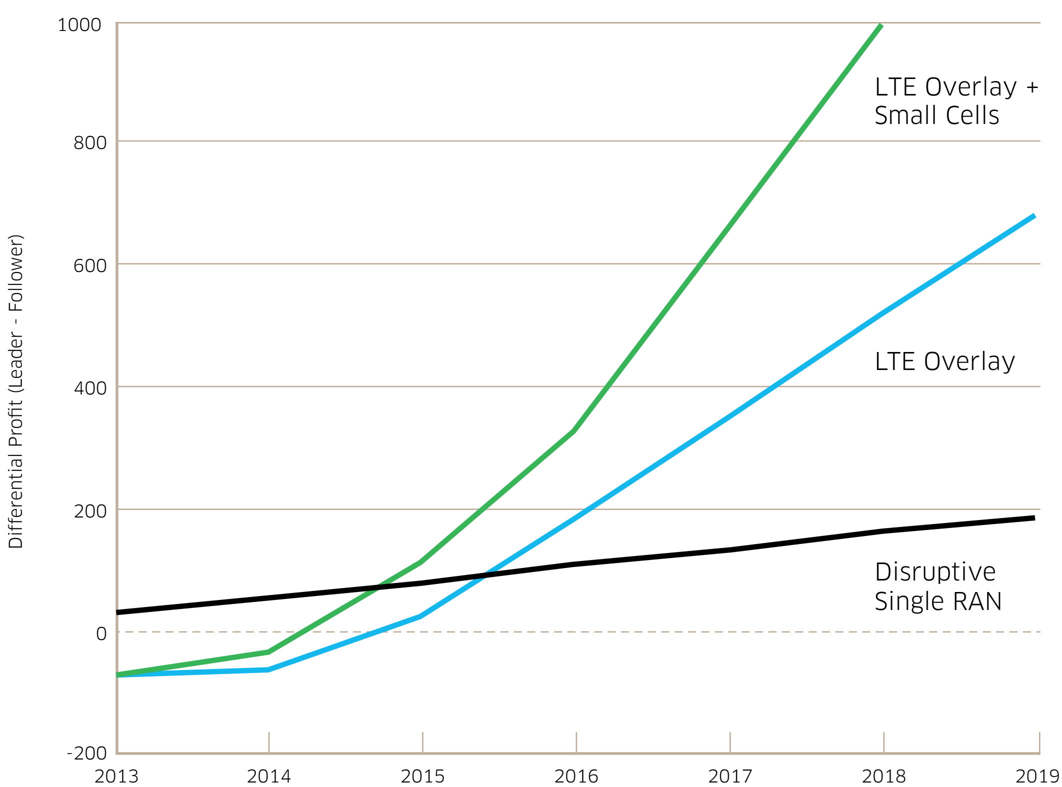


Looking at Figure 3, it is clear that the maximum cumulative profit is achieved by deploying LTE as early as possible (in 2013 in this example) and then in subsequent years the cost advantage of LTE overlay allows the first mover to steadily accumulate profits, at the expense of the players deploying Single RAN. Furthermore, if the Leader reinvests these profits in further network expansion, the advantage is perpetually increased, with the followers increasingly unable to compete.

This is the central result of the model: moving early to LTE and deploying as fast as possible is a strategy that is guaranteed to win versus Single RAN-based players.

Another way to view the gain of the Leader with respect to the Followers is to plot the differential profit between the two, as shown in Figure 4 for two scenarios: the Leader deploys LTE as an overlay or LTE overlay plus Small Cells, and the Follower deploys a Single RAN strategy. We also include a third scenario, in which the Leader also deploys a Single RAN strategy but uses a unique advantage (e.g., in regulation or business arrangements) to offer more capacity, which in turn will modify overall market pricing, forcing the (Single RAN) competition to compete at a new price point. We call this case a 'Disruptive Single RAN' strategy.

Figure 4. Output of the game theory model showing the relative profitability advantage of the Leader deploying LTE and Small Cells compared to a Follower deploying Single RAN. Also shown is the case where one market player disrupts the market with a Single RAN with a unique offer to gain advantage



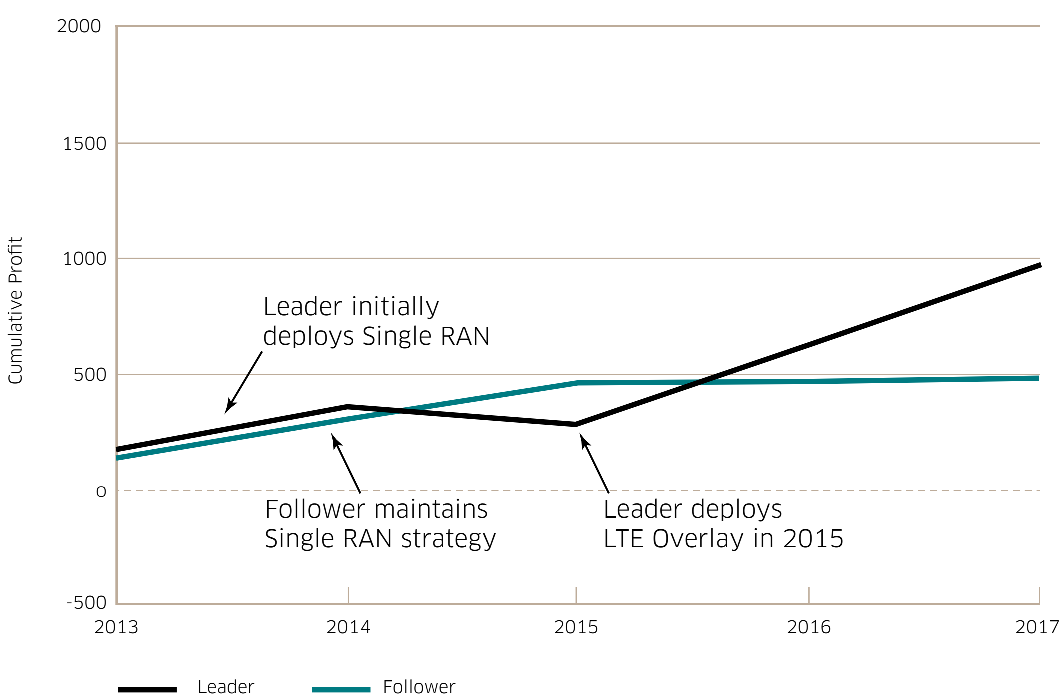
From Figure 4, it is immediately apparent that by deploying LTE or LTE Small Cells an operator will gain sustainable market advantage and exponentially increasing profitability. Furthermore, the gain realized by this strategy is larger than any gain resulting from simply maintaining a Single RAN deployment.

It is instructive to reference these scenarios to real world examples, as follows:

- **Disruptive Single RAN:** This is the strategy employed by Free in France to gain market advantage relative to the 3G incumbents. Notably, the incumbents' response has been to begin to aggressively deploy LTE Overlay to regain market advantage, as discussed further below.
- **LTE Overlay:** This is the strategy employed by Verizon Wireless to gain market advantage from a position of disadvantage in 3G. Notably AT&T was forced to respond with a similar LTE Overlay strategy to reduce the competitive disadvantage.
- **LTE Small Cells:** This is the strategy now being contemplated by AT&T to regain market advantage.

From the above, we can conclude that the game theoretical analysis is indeed playing out in the actual marketplace. We now examine one other case of interest — a competitive Single RAN market where all players defer investment in LTE for a prolonged period, and then one player changes its strategy to deploy LTE in an attempt to gain a sustainable competitive advantage.

Figure 5. Illustration of the market advantage that can be achieved even with a delayed LTE Overlay strategy



As shown in Figure 5, the Leader initially tries to gain market advantage by deploying more Single RAN capacity than the competition but at the same cost structure. Therefore, no sustainable advantage is achievable and the decision is made to move to an LTE overlay strategy after two years. Once again a market advantage appears for the Leader that will drive a sustainable profitability difference.

SUMMARY

In conclusion, by analyzing the profitable growth possible by employing different wireless technologies, we are able to demonstrate that the route to maximum profitability is always to employ LTE, or LTE Small Cells, and that these strategies will allow at least a 10x increase in wireless capacity to be deployed by operators. We further show using game theory that operators deploying Single RAN approaches always lose to an LTE-based deployment by a competitor. This is borne out by comparison with current market dynamics, which validates our analysis and conclusions.

APPENDIX

Stackleberg model details

The Stackelberg model is a strategic game in which the leader moves first and then the followers move sequentially. The input to the model is the cost function for each player as a function of quantity provided, and a market price as a function of total quantity offered by all players in the market. The output from the model is the optimal quantity of goods that can be offered by each firm. From these quantities one can compute the market price and the profits for each market player. In this analysis, we have used linear cost functions and an elastic supply curve as the representation between quantity and price.

The classical Stackelberg model computes equilibrium quantities and thus has no explicit time dependence. So, we have extended the model to include a simple time-dependence by computing the Stackelberg equilibrium quantities in a series of time slices. Each time slice potentially has a different cost function for each player based upon the deployment of a new technology, allowing a different decision to be made by each player at each point in time. The cumulative profits are computed by adding the profits computed in each time slice.

Assumptions and definitions

Cost Functions: A function representing the cost for a player in a Stackelberg game to supply a given quantity of goods. We assume linear cost functions to represent the service provider costs to deliver a fixed quantity of data.

- **Single RAN:** $15M / Petabyte
- **LTE Overlay:** $12.5M / Petabyte (250M to deploy spread over 3 years)
- **Small Cells:** $10M / Petabyte (300M to deploy spread over 4 years)

These costs are very conservative; the cost differential between 3G and LTE may be significantly larger in practice, further favoring the LTE players.

Market Price Functions: A function representing the price of goods in the market as a function of the total quantity of goods offered to the market. We assume an elastic pricing model, meaning that there is 'pent up demand' in the system. Coefficients are selected based upon an assumption of $30/month for 1GB of data.

Leader: The player in a Stackelberg game that uses an existing advantage (market, technology, incumbency) to proactively set market supply. The optimal Stackelberg Leader supplies a quantity based upon the explicit assumption that the other player(s) must reactively set their quantity supplied based upon the supply set by the Leader.

Follower: The player in a Stackelberg game that reactively sets its quantity supplied to the market based upon knowledge of the Stackelberg Leader's supplied quantity.

ACRONYMS

LTE	Long Term Evolution
QoS	quality of service
RAN	radio access network

AUTHORS

Marcus Weldon
Mark Bass
Subra Prakash
Chris White
Iraj Saniee