Trains, Planes and Automobiles

Delivering Broadband Connectivity at High Vehicle Velocity

Whitepaper

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1. Executive Summary

The telecommunications industry is evaluating various radio access and core network technologies for deployment of IP-based mobile broadband services, often referred to as “Beyond 3G”. This is somewhat of a misnomer given that mobile broadband based on a “true” IP architecture is already being deployed by Flarion operator customers in Europe, the US and Asia. There are many companies claiming the mobile broadband data crown and positioning their particular technology flavor as comparable to fixed broadband. Multi-megabit data rates and low latency are seen as the new mantra, even though Flarion has been flying this particular banner for the past 4 years. The difference is that alternative networks have now been deployed and technology performance comparisons can be made.

This whitepaper considers the high speed mobility requirements of trains, planes and automobiles and provides definitive data on actual system performance in connecting these three different mobile platforms. In addition, basic criteria is suggested for evaluating technology performance of mobile broadband IP-based networks

At Flarion, the belief holds true that performance claims have to be based on solid evidence from technical and market trials and more importantly, from commercial deployments. All the performance figures provided in this whitepaper have been witnessed by major global operators and in many cases publicly verified.

Flarion believes that the telecommunications industry is at a tipping point, where mobile convergence predicted by many industry pundits is already happening. Operators have spent the past 2-3 years evaluating various technologies to validate their performance claims and suitability for commercial deployment. The speed of the transformation from voice centric delivery to data centric service provisioning will be accelerated by technologies such as FLASH-OFDM® which has been rigorously tested in both technical and commercial deployments.

Both IDATE and Informa Telecom predict wired broadband connections to be 190-200 million globally at the end of 2005, growing to 450 million+ by 2009. This, in turn, will accelerate the growth of mobile broadband connections in a similar way that fixed voice was mobilized by GSM and CDMA technologies.

Some operators will be innovators, moving quickly to acquire early market dominance in their chosen areas while others will take a followers strategy. We believe the evidence, some of which is contained in this whitepaper, demonstrates that the industry is about to dramatically accelerate the move to OFDM-based mobile data networks. Innovators will therefore be the early winners.

2. Introduction

Telecommunications service providers and transportation agencies are currently evaluating the next steps for the delivery of mobile broadband data services. One of the key evaluation criteria will be the ability of the technology to deliver a DSL-like broadband experience to multiple users while mobile, anywhere and everywhere. There has been a great deal of discussion centered on portability compared to mobility and how relevant each is to customers. In truth, this debate is irrelevant. A portable only broadband data service will limit the market opportunity for operators to WiFi-like hot spots and constrain the revenue opportunities that are needed to keep the industry sector from falling into commoditization, low growth and low returns.

A fully mobile data service must be able to deliver a true mobile solution, enabling broadband access to all transport vehicles from trains to planes to automobiles. The intrinsic requirements for broadband services include full access to the Internet, secure Intranet access (VPN) and converged voice, data and broadcast services. Broadband data is not just about laptops, or computers in homes or offices, it is about creating a ubiquitous mobilized data network that looks and feels like fixed broadband. It is a network where myriad terminals both stationary and mobile are always connected, services are easily accessible and access is competitively priced.

This whitepaper considers what is already happening in the mobile data market and at the kind of performance and data rates that is already being experienced by customers. While existing technologies and mobile data networks are providing incremental improvements to current networks, they are unlikely to deliver in the short to near term the broadband data service set that will spur growth.

Over the last three years, FLASH-OFDM has been rigorously field-tested in various scenarios, including but not limited to trains, planes and automobiles, with various global operators around the world. This whitepaper illustrates why Flarion is convinced that broadband mobilization in all transport scenarios is already happening and focuses on the impact of vehicular velocity, network metrics and user experience.

3. Data Rate vs. Vehicle Velocity

Few companies detail the data rates actually achieved in their networks and fewer compare the impact of vehicle velocity on those rates. Whereas acceptable service levels can be achieved while stationary, the ability to maintain the same high service levels while moving at speeds up to 250km/h is the key competitive advantage that mobile operators have built their business cases around for the past 15 years. Data rates are reduced when a terminal is mobile due to the rapidly changing RF conditions, so mobile technologies have to be designed from inception to accommodate mobility phenomenon, otherwise network performance and bandwidth utilization will be compromised.

Two main criteria need to be met to ensure a high performance data network in a mobile environment:

- High peak and average data rates that are comparable to fixed services. Currently this benchmark is an average of 1Mbps in the Downlink and 256kbps in the Uplink at similar contention ratios
- Limited degradation of data rates when moving at speeds in excess of 100km/h

FLASH-OFDM was designed from the outset as an IP-based mobile broadband service, unlike other data networks available today. As demonstrated in this whitepaper, FLASH-OFDM is the best technology currently deployable, delivering a commercially viable service that meets the above criteria and is comparable to the user service levels experienced in a wired broadband network.

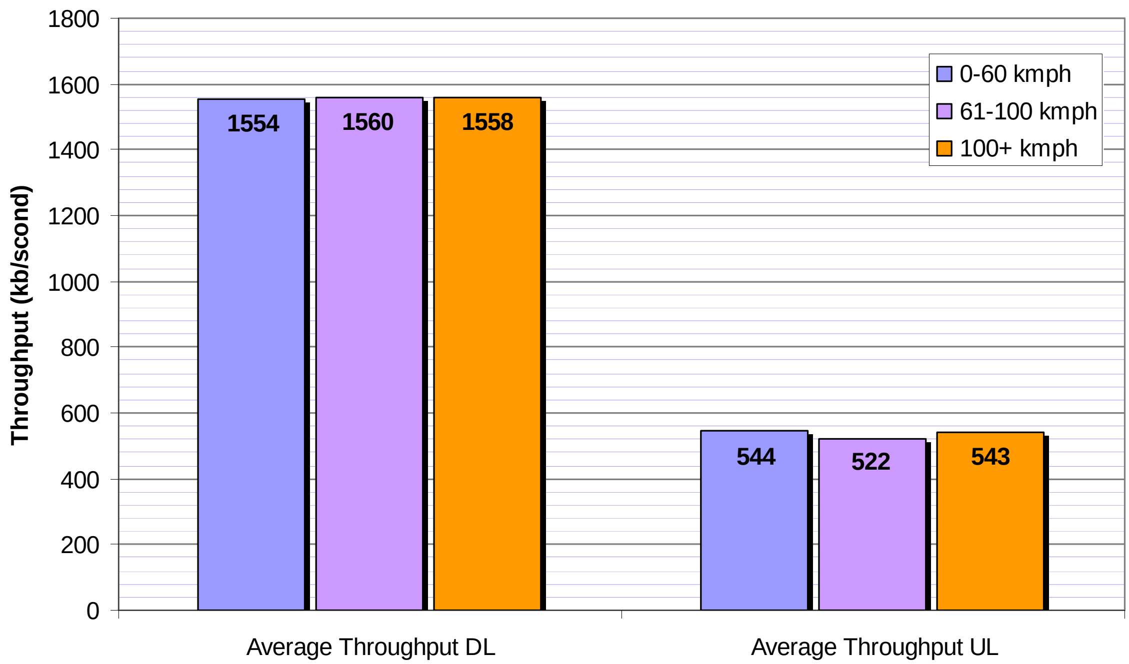
4. Trains

The railway industry is at the cusp of investing in dedicated mobile broadband networks to deliver seamless data services, primarily targeted at business customers. There are three options to delivering this type of train service. A dedicated network covering the rail tracks providing good service inside the carriages to users with laptops equipped with suitable PC cards. A second option is to provide the coverage from an existing, non-rail dedicated network, such as WCDMA or CDMA EV-DO for instance and enhance the coverage where there are service gaps.

Alternatively, WiFi can be installed inside each carriage with a mobile broadband network deployed as the backhaul technology. This option would mean that higher gain antennas could be used on the trains and fewer sites would be needed to provide ubiquitous coverage of the rail network. A key advantage of this approach stems from the fact that there is no need for users to purchase a dedicated PC card to use the service since many new laptops are WiFi enabled. This greatly enhances user adoption.

Graph 1, outlines key performance data from a FLASH-OFDM railway network that has been covered using multiple sites over more than 145km of track. Average throughput of more than 1.5Mbps is achievable at speeds well in excess of 100km/h.

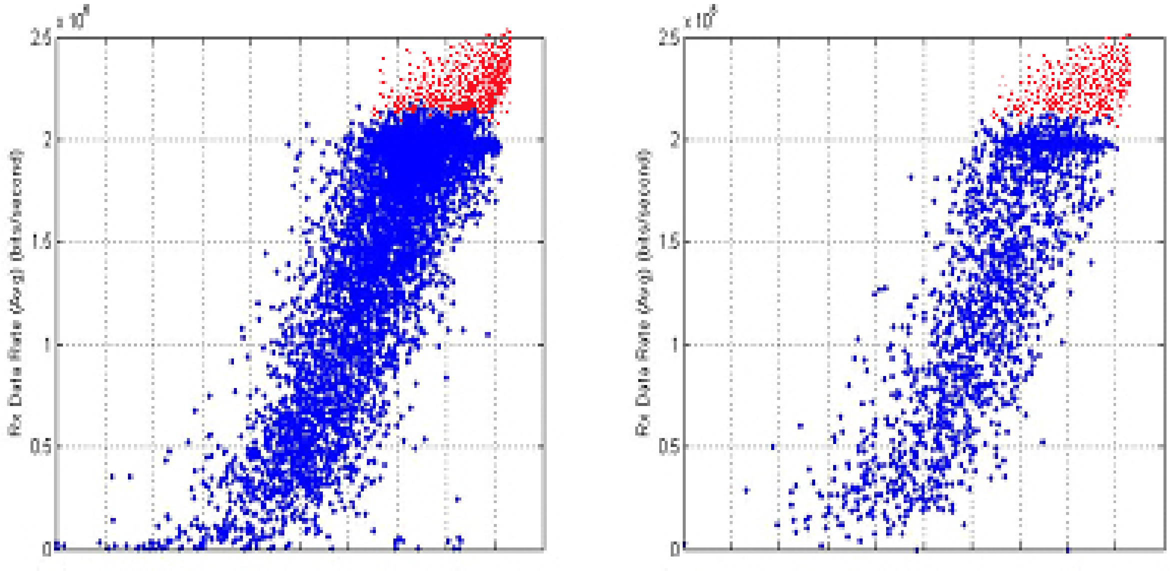
Graph 1: Average Data Throughput in a FLASH-OFDM Railway Network



As can be seen from the data, the average throughput in both the downlink and uplink is only marginally affected by velocity. Even at speeds in excess of 100km/h the average data rate is above 1.5Mbps. Network latency while traveling at speeds above 100km/h averaged 33ms and was not materially impacted by the speed of the train.

This dedicated FLASH-OFDM train network delivers high data rates at high speed because the network can be optimized for a train traveling on a fixed path, external antenna are used and there is less variation in the RF conditions. There is limited multi-path interference due to good network design and mostly only Doppler shift to impact signal quality and data rates. Unlike non OFDM based technologies, FLASH-OFDM handles Doppler shift extremely efficiently delivering high average data rates across the whole rail network.

Graph 2: Data Rate vs. SNR – FLASH-OFDM Railway Network



Scatter Graph for data rates all speeds

Scatter Graph for data rates above 100km/h

Data rates versus SNR at all speeds and above 100km/h were plotted on two scatter graphs, (Graph 2). There was no statistical difference between the two results indicating throughput is not impacted dramatically by an increase in velocity.

Peak data rates level out at 2Mbps due to a single E1 (2Mbps) backhaul at each cell site which limits the total network throughput. This also reduced average data throughput. The red portion of the graphs shows measurements from a site not restricted by the backhaul network.

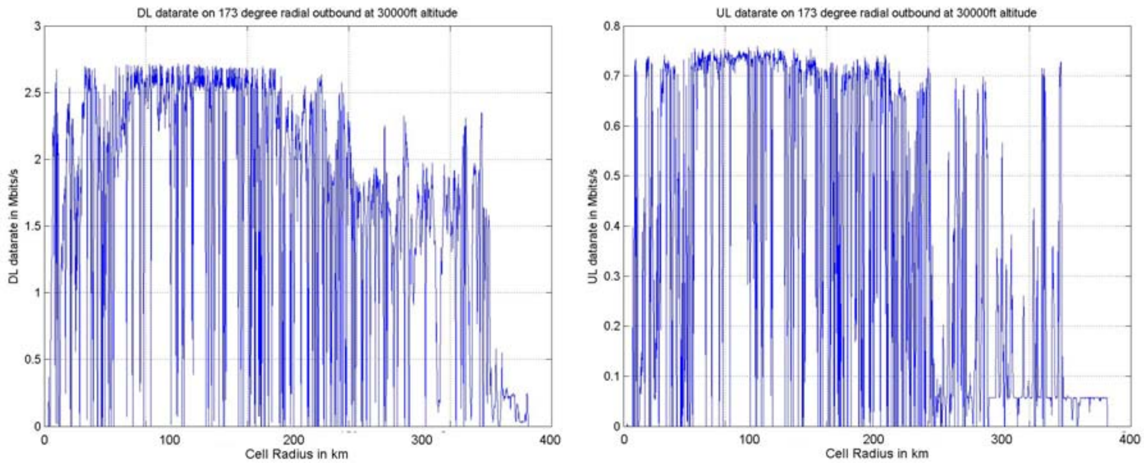
There are less data points on the right hand graph since measurements below 100km/h are excluded – however the overall "scatter" of the data points are almost identical to the left hand graph demonstrating that FLASH-OFDM performance is not materially affected by high speed.

5. Planes

In certain ways, providing a mobile broadband service to aircraft is less complicated than to trains since there are more line-of-site occasions and less interference caused by structures and terrain. Due to these properties the cell sizes can be very large. Graph 3 details the downlink and uplink data rate achieved at varying distances from the cell site using FLASH-OFDM in a ground to air network configuration.

In early 2004, Flarion tested in-flight communication for voice and broadband data on the East coast of the United States. The aircraft was flying at a height of 30,000ft, (9,000m) and service was sustainable up to about 360km from the cell site. Data rates above 2Mbps in the downlink and 700kbps in the uplink were achieved at distances up to 320km while traveling at speeds in excess of 300km/h. Latency was also below 50ms. Overall these tests validate that FLASH-OFDM is a very versatile technology for the delivery of IP-based mobile broadband services in a variety of situations.

Graph 3: Peak Data Rates at 30,000ft – FLASH-OFDM



5.1. Airborne Capability

While the mass market deployment of in-flight broadband is still at an early stage, Flarion has demonstrated that it is relatively simple to achieve the delivery of an airborne service for both private and public organizations. Flarion has demonstrated mobile broadband can greatly benefit institutions looking to take advantage of instant access to critical data and fast communication with colleagues. In both private networks and in technical trials via partners and with government bodies, Flarion has demonstrated the flexibility of FLASH-OFDM to deliver ubiquitous coverage and to mobilize Internet access, in particular for homeland security applications. In many cases communication with airborne support vehicles is a key component that enables law enforcement agencies to maintain ground to air communication and share vital information.

6. Automobiles

Mobile broadband is not just about computing portability or laptops in the back of taxis. There is a potentially large applications market including telematics, in-car navigation systems, vehicle tracking for both insurance and road tax charging and broadcast services to name just a few. There are no reasons why cars, buses, commercial vehicles, taxis, motorcycles, and even ships and boats could not be broadband mobilized by technologies such as FLASH-OFDM.

Numerous technologies are proposed to address some of these market opportunities yet few are based on a true IP architecture or have the full capability to deliver on their initial promises. Claiming to be a mobile broadband solution, quoting low latency and high data rates is not the same as delivering a standardized IP compliant network with consistent performance at high speed. Flarion has spent the past three years satisfying the stringent requirements of operators around the world and proving the significant advantages FLASH-OFDM delivers compared to most other alternatives.

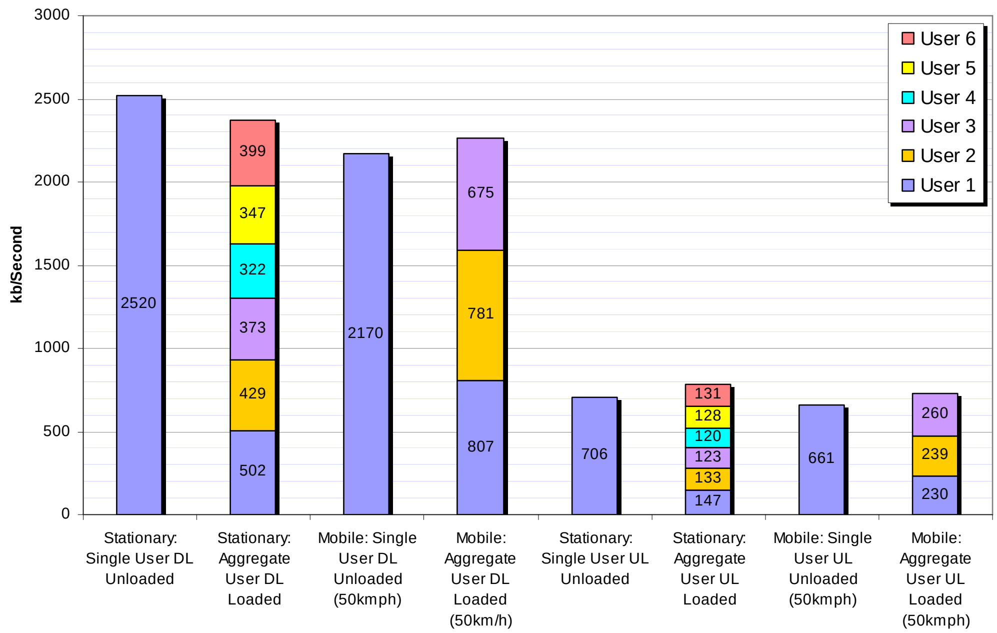
Once vehicles are connected to a high capacity ubiquitous mobile broadband data service, the dynamics of the industry will change and operators will be free to exploit new revenue opportunities. Penetration rates will almost become meaningless as devices proliferate via a multitude of new applications and services.

Flarion has been through the testing and performance validation of FLASH-OFDM and commercial networks have been launched in the US and Europe. More operators will select the technology and launch networks in the coming years. This adoption will accelerate as FLASH-OFDM becomes a global standard during 2006.

7. Data Throughput Results

The majority of current wireless data networks are not yet capable of delivering a wired DSL like experience. Mobile Broadband is where the growth is and where the industry is currently focused. Existing mobile data networks are excellent for voice and narrowband data services to small mobile devices, but will be unable to deliver a true IP-based ubiquitous mobile broadband service even with enhancements such as HSDPA and EV-DO Rev. A. This is the area where OFDM and in particular, FLASH-OFDM can bridge the digital divide. Graph 4, demonstrates the actual throughput in a FLASH-OFDM cellular network at 2.1GHz with single and multiple users in both stationary and mobile conditions.

Graph 4: Data Throughput Results from a FLASH-OFDM network



Mobility in this network has a somewhat larger impact on data rates when compared to the rail network. It is far easier to optimize RF to cover a single track than multiple auto routes and the rail network has generally more line of site situations than in a typical cellular network. Despite this, FLASH-OFDM delivers a superior performance when compared to competing technologies, which is remarkable, considering that the technology uses only 1.25MHz of paired spectrum.

7.1.1. Stationary Data Throughput Results

With a single stationary user in the cell, all throughput was available to one customer resulting in a data rate of 2.52Mbps in the downlink and 706kbps in the uplink. This was in good SNR (Signal to Noise Ratio) conditions. Since cell data throughput is contention based, with multiple users, the total throughput is shared between, in this case six users. The result, as can be seen from the graph, was that each user received a portion of the available data resource, resulting in average data rates ranging from 502kbps to 322kbps in the downlink and between 147kbps and 120kbps in the uplink.

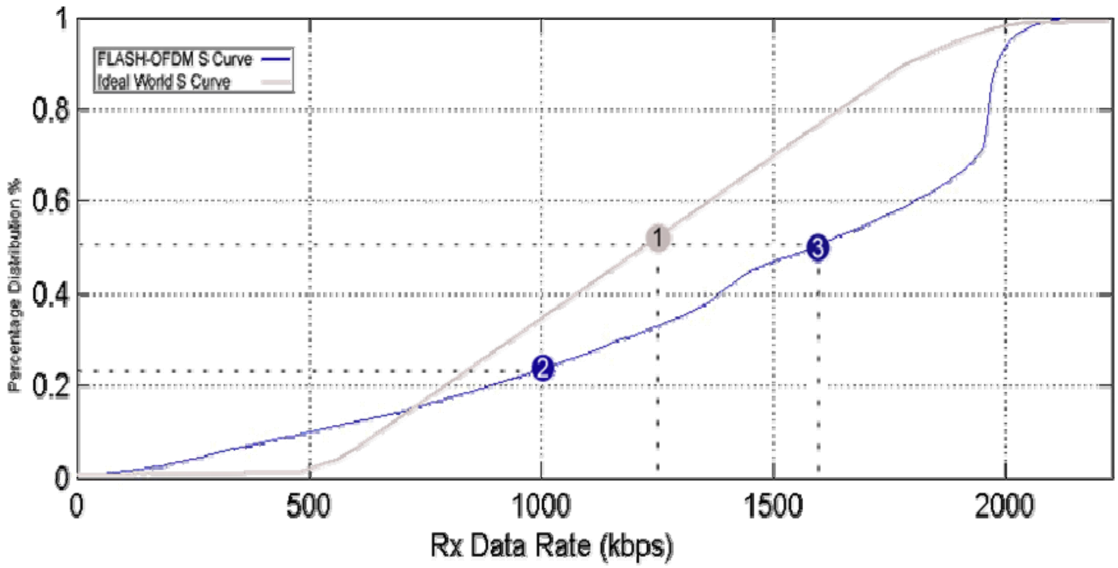
7.1.2. Mobile Data Throughput Results

Mobility, as expected, resulted in a slight fall in user data rates due in part to the varying SNR conditions in the cell. There was a reduction in the downlink data rate to 2.1Mbps and 661kbps in the uplink for a single user traveling at 50km/h. As the number of users increased the total cell data resources were shared between each user. In the case of three mobile users all traveling at 50km/h, data rates ranged from 807kbps to 675kbps in the downlink and from 260kbps to 230kbps in the uplink.

8. Cumulative Distribution of Data Rate

When traveling at high speed, especially in a train network, cell edge data rates are less important than the overall cell performance. At high speed a vehicle will pass through an area of varying RF signal strength very quickly. The impact of cell edge areas on performance will therefore be minimal, providing the rest of the cell area delivers high average data throughput. The significant performance measure is Cumulative Distribution of Data Rate, (CDDR), in effect, the amount of time that data throughput is above a specific level. Graph 5.

Graph 5: Cumulative Distribution of Data Rates in a FLASH-OFDM Rail Network



In an ideal world a mobile operator would prefer a smooth CDDR "S" curve, the grey line in the graph, with little or no occurrences of low data throughput as seen on the left of the CDDR curve, an even distribution spread across the main data throughput region, then reaching a maximum limit reflecting system peak data rate. In Graph 5, the ideal CDDR "S" curve at point ①,suggests that for 50% of the time the network is delivering data rates at or below 1.25Mbps. If this is true, then for 50% of the time the network is delivering data rates at or above 1.25Mbps.

In a FLASH-OFDM network under real high speed train network conditions the collected data demonstrates greater that 1Mbps in 75% of the samples, point ②. The CDDR curve for any mobile data network will define the level of data service that an operator can be confident in delivering in their mobile broadband network, in high velocity conditions. For a 1Mbps mobile broadband access service this should be with a minimum CDDR of 50-50% at 1Mbps. The CDDR 50-50% for FLASH-OFDM is 1.65Mbps. (Point ③).

9. Conclusion

Some of the available wireless data technologies can meet the stringent performance requirements of mobile broadband access, although few can meet performance criteria consistently, for all transport platforms and at high velocities. Making unrealistic technology claims does nothing to progress the telecommunications industry and is more likely to alienate opinion leaders, operators and vendors and create a growing undercurrent of skepticism. Flarion's objective is to create an optimistic industry view of mobile data by clearly communicating the performance criteria that are viable today and in the near term. In addition, well defined benchmarks and Key Performance Indicators (KPIs) such at latency, average or sustainable data rates and CDDR performance have to be agreed so that both operators and customers have confidence in the network technology and ultimately, service delivery.

FLASH-OFDM is one technology that has been thoroughly tested over the past three years and is now validated by operators as a commercially deployable mobile broadband access solution. Average data rates both downlink and uplink as well as latency are comparable to wired broadband even when a user is moving at high speed. Commercial FLASH-OFDM networks are in service for both mobile (train and automobile), and for fixed/portable usage, plus Flarion has demonstrated the viability of ground to air network deployments. Numerous FLASH-OFDM terminal models are available, customer growth is accelerating and will continue to do so. The potential to broadband mobilize the business community and deliver on the past promise of the Mobile Internet to consumers will be dwarfed by the total mobile broadband transport market of trains, planes and automobiles.

Market penetration by population will soon be a distant market metric as all transport medium becomes ubiquitously connected. Business usage will migrate to a broader consumption of data and Internet access as voice, data and broadcast convergence starts to become a reality and mobile broadband access permeates all aspects of our lives. Operators therefore need to ensure that their technology choice is well proven and demonstrable for delivering not just sustainable multi-megabit data rates and low latency, but can consistently do so at high vehicle speed.