Powerwave Technologies Inc. contribution to
GN Docket No. 09-157 and **GN Docket No. 09-51**

Section II, subsection A 11

The FCC Notice of Inquiry GN Docket No. 09-157 and GN Docket No. 09-51 is seeking comments regarding what new policies it might consider to spur wireless innovation to achieve the goals of generating new investment, creating new services for consumers and increasing overall economic development and consumer value.

We believe that wireless technological innovation through the process of new technology invention and development will provide the largest contribution to the achievement of these FCC goals for wireless innovation and, that FCC policies supporting the generation and market adoption of new technologies will provide the FCC the leverage for its greatest impact.

In the history of wireless technologies and network architectures, the nature of technology itself has largely determined how spectrum is shared, which in turn has constrained choices as to how to allocate spectrum among those who wish to utilize it. As technology has evolved, new forms of allocation of spectrum have become possible. In addition, as technology has evolved new patterns of capital investment and management have become possible. Spectrum allocation, capital investment and management are the key drivers that shape the wireless industry and its industry structure. This in turn sets the landscape where a combination of government regulation and market investment and management will seek to influence the growth and evolution of the industry, its structure, and its contributions to achieving the FCC's goals.

In order to bring wireless services value to consumers, the first commercially deployed cellular wireless technologies were "fit-to-purpose" for wide area voice communications, and required large scale infrastructure deployment owned and operated by network operators who could organize large centralized capital formation, manage asset concentration, purchase and control adequate spectrum and manage extensive end-to-end network operations with device control and ownership; and importantly, control proprietary services delivery to consumers. Associated FCC policies focused on spectrum allocation, assignment and licensing, and technical performance specification such as power limits, guard bands and interference controls. This market structure captures the preponderance of consumer wireless value delivery today. While cellular technologies and architectures continue to evolve, improve, and become more capable, especially with the addition of operator provided data, video and certain Internet services, the original market structure remains in place and the rate of wireless innovation is determined by it.

Later FCC policies introducing unlicensed spectrum and operating rules for "free" public use invited and spurred the introduction of new technologies and architectures into the market, such as WiFi, with a new "fit-to-purpose" design focused on local area high-speed data communications supporting higher grade video and Internet services. WiFi employs low cost non-proprietary computer sector components and software, which in turn allowed for the formation of a new market structure with new participants and

innovation where network and device assets are much more decentralized, independently financed, owned and controlled and where spectrum is “free” but shared amongst all users. With WiFi, large and small businesses as well as consumers can own and control their own networks and devices and new business and consumer services development and delivery is Internet based with no limits on end-user use and value derivation. The introduction of unlicensed spectrum expanded wireless innovation by enabling new technology development by new wireless sector manufacturer participants and entrepreneurs that in turn enabled new entrepreneurial services development not deliverable via cellular technology based networks, creating a new market for investment, economic growth and consumer value.

Recently, the FCC has ordered the establishment of “whitespaces” spectrum for market use. In sum, the use rules governing “whitespaces” radio network and device operation in the earmarked spectrum provide for the operating protection of incumbent or registered operators in any particular spectra and geographic territory by employing new registry data base, power limits and radio sensing technologies requirements to determine if a new radio entrant has “freedom-to-operate.” While this new spectrum use definition brings more available spectrum to the market for use by businesses and individuals, effectively this new “whitespaces” regime operates the same as the unlicensed WiFi based market as between all non-incumbent operators. More innovation can be expected once the “whitespaces” market begins to develop, but the technology trajectory will be path dependent, most likely following that of WiFi.

Essentially, the summary above shows that technology and regulation co-evolve, with new technology development leading the way in discovering what new value creation is possible, enabling more enlightened regulation to stimulate and promote equitable market use of the precious national spectrum resource for maximum societal benefit, consistent with the stated FCC goals. In this context a new class of wireless technologies is emerging in what is known variously as the “smart” or “cooperative” or “cognitive” class of radio technologies and architectures. We believe that the development of these technologies and the markets they can unleash by the FCC promulgating appropriate new rules for spectrum use can allow the FCC to advance its goals again, as it has before.

With the recent advent of smart peer-to-peer radio technology as demonstrated in military programs such as SINCGARS, ELPRS and DARPA XG it is possible to build broadband wireless mobile ad hoc networks (MANET) using small format radios. MANET radios have demonstrated a new approach to wireless and a new “fit-to-purpose” design that of “metro-area” delivered very high-speed data network supporting more robust video and Internet applications. In this approach the radio uses distributed computational processing across a cluster or clusters of radios in order to support the execution of advanced “cooperative” and/or “cognitive” control protocols. In addition, they use less complex, more robust waveforms designed specifically for peer-to-peer communication at extremely high capacity and high quality using a given spectrum bandwidth or opportunistically using dynamic spectrum awareness algorithms to recover “whitespaces”.

Traditional cellular systems and WiFi systems employ the concept of a master arbiter a.k.a. a base-station to manage all channel communications within a cell using a “hub and spoke”, tower based, architecture. These systems are coverage, power and capacity limited as determined by the laws of physics, i.e. “Shannon’s law” - the signaling limitation that determines the maximum bps/Hz for a given transmission from a tower to a handheld within a cell. All cell phones compete for access spectrum with all other cell phones in a given cell and therefore the base-station is unable to reuse channel spectrum once it is allocated to a particular call. The only effective means for spectrum reuse in a cellular network is to decrease the size of the cell, thereby reducing power and coverage.

MANET networks take the concept of cell size reduction to its limit case where the cell phone is the cell. MANET radios coordinate amongst themselves to share spectrum and effectuate interference avoidance in ways that can increase spectral reuse for device-to-device and device-to-backhaul broadband connectivity in any given spectral regime to levels far greater than current base station and WiFi type technical architectures. Since these radios are designed to “whisper” they allow many more parallel transmissions within a given geographic area than a traditional “tower and power” cellular network, thereby increasing network tele-density and throughput per unit area. They are designed to maximize bps/Hz/m^2. In other words, a MANET radio leverages “Moore’s law” - the doubling of CPU processing capacity every 18 months to drive higher levels of distributed computational cooperation and cognition rather than be limited by the complexities of signal processing over a large area cell.

MANET radios also distinguish between “cooperative” and “cognitive” radio algorithms. Effective operation of a smart "cooperative" radio system in any given spectrum band requires all the associated "smart" radios operating in that band to interoperate to some level and be equivalently capable regarding basic shared frequency use cooperation and coordination. Whereas, a “cognitive” radio does not need a priori interoperability capability with the other radios in a given band providing it can detect and avoid interfering with the other radios. Cooperative radios can drive spectrum utilization to extremely high levels of data throughput saturation in a given band, whereas cognitive radios drive higher levels of foreign emitter occupancy in a given band. Both types of radios are useful and when combined together they can provide a future proof network capability for any type of licensing regime, so long as the minimum “cooperative” or “cognitive” spectrum use rules are provided for spectrum sharing by these technologies.

Smart radio technologies also support “spectrum neutrality” i.e. a set of use rules for new spectrum allocations and assignments, much the same in concept to the Internet “network neutrality” concept, where networks and devices can maximally share spectrum. Spectrum neutrality embraces simple rules that enable devices of many shapes and sizes to communicate across the same spectrum. This principle is essential if we are to have free development of new uses, applications and devices for wireless. The arguments that support spectrum neutrality are similar to those of network neutrality. Both radio spectrum and the Internet are public media over which communication can be established. The fact that one exists "in the ether" and the other requires capital investment and operation tends to obscure their essential similarity from the standpoint of applications, users and devices. The benefits of neutrality in electronic,

physically-mediated networks was established long ago and has currently reached a crescendo of relevance in addressing the Internet, and most independent observers agree that Internet network neutrality is essential to promote innovation in uses, applications, devices and communication architectures.

The same is true for radio spectrum. Wifi and Bluetooth are contemporary examples of this principle in action. Today we are attempting to regulate "white spaces" in line with principles of neutrality. Spectrum neutrality requires regulation, a minimal set of technical rules to ensure that devices can inter operate and cooperate. It is vital that we adopt spectrum use rules that are as minimal as possible, so as not to create barriers to entry. We need to examine closely any regulations to ensure that they truly support neutrality, rather than tacitly favor a particular approach or party. We need a principle of minimum effective device regulation for maximum sharing of resources.

Wife and Bluetooth devices are rather primitively regulated in order to achieve interoperability. Power limits, crash-detection and shared-communication protocols suffice. While these elements of regulation have been admirably minimal and open, the technology they support can only go so far in resource sharing, especially cooperative spectrum reuse. Today we can achieve a much higher level of spectrum neutrality and resource sharing with MANET technology. In order to embrace MANET build-out, our regulation needs to focus principally on waveforms and computational algorithms, rather than power limits and crash detection.

We believe that the approaches currently being examined for "white space" do not sufficiently reflect the advances in technology that have been achieved since the days of Wifi and Bluetooth and their like. Essentially, proposed regulation focuses on geographic separation buttressed by registration, combined with power limits. The result will be a massive waste of spectrum compared to what can be utilized with currently available advanced technologies for cooperative and cognitive radio.

It is important to emphasize, as with WiFi, MANET type “cooperative” and “cognitive” radios employ low cost computer sector components and software, can enable for formation of a new market structure with plenty of unlicensed interference free spectrum for true wireless broadband operation, low barriers to entry for new participants and innovation where network and device assets are much more decentralized, independently financed, owned and controlled and where spectrum is “free” but shared to a much higher degree than either WiFi, or indeed cellular, amongst all users; and importantly, with much higher data throughput, very high spectral reuse and very high quality. The introduction of FCC rules supporting “spectrum neutrality” will stimulate and buttress entrepreneurial innovation focused on the “cooperative/cognitive” wireless path technologies and the new markets they will help create.

We recommend that the FCC do a rigorous examination of new technologies for spectrum-neutral sharing of frequencies. The results of this examination would then be used to craft regulations to encourage implementation on a wide scale of more advanced technologies. Our belief, as explained below, is that the result could be an explosive increase in the use of broadband wireless technology in the United States,

several orders of magnitude larger than that achieved by the Wifi and Bluetooth generation of devices.

We suggest that the FCC promote wireless innovation in both the "cooperative" and "cognitive" generic class of radio technologies by allocating sufficient spectrum with appropriate associated spectrum use rules so industry and individuals can support new opportunistic investment in such technologies in order to accelerate innovation and market diffusion of new economic and consumer value, much as it had done earlier with unlicensed spectrum which ushered in the WiFi market innovations and values. Therefore, we propose one policy addition which the FCC can consider is the identification and/or allocation of spectrum for "cooperative" and “cognitive” radio use where the FCC can mandate technical specifications and rules for device and infrastructure cooperative/cognitive operation. These specifications and rules can be applied to the current "whitespaces" spectrum, or to newly identified spectrum that might otherwise be allocated as unlicensed spectrum but should be allocated as "cooperative/cognitive".

Section II, subsection A 12

The Internet is a mega trend that has defined the transition of voice to data, from switched networks to packet networks and the transition of business from proprietary practices to the Internet and a connected world. This mega trend has yet to permeate the Cellular Radio Access Network (RAN), which remains a proprietary, closed and very complex sub-network. While 4G has spurred new waveforms, chips and antenna technologies the RAN continues to pattern the original G's in terms of a “fit to purpose” voice centric, switched circuit, architecture where each channel is managed by a central base station controller (cf. with a class 5 switch where each subscriber channel is managed by the stored program control system). If the RAN could be extended to be part of the Internet edge network then it is likely that new higher performing, lower cost, networks could be launched leading to better price/performance devices and applications.

As an example, WiFi has had a major influence in realizing 3G broadband, without it a 3G user device would not be able to be distinguishable from a 2.5G device in terms of capacity operation and utility. The WiFi stack is designed to be IP compatible and there is no requirement for a manufacturer proprietary RAN. The integration of WiFI and 3G networks has encouraged new devices, software architectures and 3rd party applications development, and encourages higher spectrum utilization and lower network costs. However, given its lack of mobility capability, coupled with the 4G's lack of spectral sharing capability has spawned new research into mobile ad-hoc underlay and overlay networks.
Mobile ad-hoc networks are being used by the DoD for field operations and that has encouraged the development of handheld IP routers with native IP as the means of communications between devices. These devices reuse spectrum in small geographic areas through advanced spectrum sharing concepts such as cooperative PHY/MAC layers and Dynamic Spectrum Awareness. These networks are characterized by peer to peer, self forming and self healing capabilities, and are able to use the same spectrum footprint for both access and back-haul operation. These networks could help existing

networks evolve to a more powerful level of price/performance operation and spur additional research by the G community into more powerful dual mode devices and increasing spectrum reuse.

Section II, subsection A 14

DARPA and the fundamental research performed by the DoD Aerospace contractors remains a key area of new wireless innovation. All the current major 4G concepts were first developed and demonstrated in the DoD community including cooperative radio technology, OFDMA waveforms, MIMO, all IP radio access networks and beam forming antennas. The commercial sector continues to rely on the stream of technology innovation that comes from DARPA and DoD sources which is then scaled both economically and technically through private capital initiatives. The greatest example of this is the Internet which was a brain child of DARPA. We would encourage more funding of fundamental research within the Government national labs, DoD and DARPA, and encourage further sharing of technology between these agencies and outside private capital.

Section II, subsection B 17

One of the most promising future applications is the realm of the "connected car". This is in the area of intelligent transportation. In major metropolitan areas lack of traffic coordination, looking for a parking space and engine idling losses account for roadway gridlock, significant loss of energy resources and productivity losses. In this new area of research the limitations of cellular and WiFi are more noticeable. Neither technology is well suited for or peer to peer communications e.g. between vehicles, or for scaled data operations within a small geographic area where there are 1000's of nodes to manage.

We believe the commission’s current focus omits this particular energy consuming application area. Furthermore, we believe that new technologies such as peer to peer radio are required to promote investment and innovation in this critical future area of energy savings and productivity gains. We would encourage the commission to allocate new policy rules and new spectrum allocations to foster new wireless solutions to the connected car problem.

Section II, subsection B 19

We believe the set aside for the 700Mhz public safety bands is critical to launching new data oriented solutions for the public safety market. Furthermore, we would encourage the commission to adopt new rules for public safety to foster new innovation to resolve critical problems facing the first responders and public safety applications. For example, it has been demonstrated that today's cellular and WiFI networks cannot resolve GPS references to three dimensions within 1-3 meter accuracy inside buildings or outside hard to reach areas, this problem effects many field personnel such as firemen, and creates undue risk in their jobs.

One possible area of fundamental research is enhanced position location through technologies like mobile ad-hoc meshed networks where multiple signal references can

be used to triangulate very accurate position location information down to the nearest meter. We would encourage the commission to adopt new rules and policies for the public safety bands to solve this position location requirement and to launch new innovation and investment in public safety solutions.

Section II, subsection C 2-27

The commissions work in providing unlicensed band non-line of sight spectrum below 6Ghz has spurred the greatest amount of innovation amongst entrepreneurs and venture capitalists in the areas of chip development, middle-ware development, software development, services development, unlicensed band products and standards development. Examples of this include WiFi and Bluetooth chip companies, unlicensed band radio and handset product companies, software stack developers and the work of the IEEE 802 committees in standards development. In addition, the public interest has been greatly served by the advent of technologies such as RFID, WiFi and Bluetooth in everyday usage in homes, cars, stores and broadband communications in general. Creating this type of wave of investment and innovation requires opening up new unlicensed spectrum bands or increasing the opportunity for secondary licensing regimes that are not likely to be auctioned off or controlled by large corporate interests since entrepreneurs and venture capitalists generally cannot "enter the game" if large sums of capital are required to "be brought to the table" before taking on an innovation market risk.

However, simply opening up more unlicensed spectrum will likely not create new innovation but rather expand existing solutions which defeats the purpose to encourage investment in new innovative technology. For example, one side effect of the current unlicensed part 15 regulation is that spectrum is still wasted since unlicensed band devices such as WiFi radios compete with each other for spectrum rather than sharing the spectrum on a fair and equitable basis. This gives rise to the "tragedy of the commons" problem where spectrum saturation can occur at relatively low levels of bandwidth throughput. What are needed are policies and rules that encourage radio cooperation and spectrum sharing.

We strongly encourage the commission to open up additional spectrum for technology innovation in the area of cooperative and cognitive radio development, where policies and rules could be set to foster the introduction of new technologies that address greater spectrum reuse and saturation. We believe that research and development in cooperative and cognitive radio technology can then be applied by the industry at large in the existing unlicensed and licensed bands providing for further increases in spectrum reuse thereby lessening the need for additional spectrum allocation. Furthermore, such innovation would help support the commission’s goals for better spectrum resource utilization, reinforce policies for more aggressive white-spaces recovery and allow for additional enhancements in the areas of secondary licensing rules for underlay and overlay networks.

Section II, subsection C 3-29

With the advent of new mobile ad hoc wireless networks there are two major new methods for spectrum access that did not exist up until this time-frame. [Mobile, ad hoc, wireless networks are peer to peer, self forming, self healing all IP networks that can be built in an infrastructure-less, minimal infrastructure or opportunistic infrastructure manner using small format and low power radios. Examples of the infrastructure variants are public safety networks where a peer to peer network can be created on the fly without access to back-haul for situation management, enterprise networks where ad-hoc radios can be land powered and tethered to enterprise infrastructure for back-haul or consumer networks where the back-haul is handled through opportunistic access to "street furniture", home DSL or cable modem.]

One access method used by such networks is based on the concept of cooperative radio technology where user terminals and fixed location radios negotiate with each other for spectrum resource on a packet by packet transmission basis using a cooperative media access control (MAC) layer that determines how communications between peers can take place with minimal interference to other radios in the neighborhood. These cooperative radios deploy such advanced concepts as neighborhood protocols that provide decision metrics for the radios to communicate in a neighborhood in parallel by controlling interference zones, modulation mode, power output, slot time, link schedule and other dynamic radio factors on a packet by packet basis. These radios operate differently to Cellular and WiFi networks which rely on a "tower and power" architecture where all radios compete for spectrum requiring a central arbiter viz. the base station to manage link and slot contention. In a mobile, ad hoc, wireless network the radios are designed to hop and to "whisper" rather than "shout", and to allow for as many parallel transmit operations (between peers) as possible in a network to drive the highest possible spectrum utilization in a given time-frequency slot.

The second type of radio is one that is dynamically spectrum aware (DySPAN) of the spectrum users in the environment and is able to adjust its operation to take advantage of spectrum holes in the environment or to use policy rules for interference to determine how aggressively to recover spectrum whilst allowing some level of increase in the noise floor or signal interference. These radios are labeled "cognitive" and require spectrum sensing capability in the PHY layer and policy controls in the MAC layer. This type of technology is ideal for white-spaces operation.

To further maximize spectrum utilization both cooperative and DySPAN technologies can be combined. Projects such as DARPA XG, the myriad of DoD products for mobile ad-hoc operation in the battlefield e.g. SINCGARS, ELPRS, SUO, SAS etc. have demonstrated the success of wireless, all IP, mobile ad hoc wireless networks and devices. With these types of networks and devices it is not particularly useful to distinguish between spectrum bands as unlicensed or licensed, or to prevent a licensed band from being used for a wireless mobile ad hoc underlay network.
We strongly encourage the commission to open up new bands and setting new rules for spurring research, investment and innovation in cooperative and cognitive radio research.

Section II, subsection C 3-30

Using smart peer to peer radio technology it is possible to build broadband wireless mobile ad hoc networks (MANET) using small format radios. MANET radios have demonstrated a new approach to wireless. In this approach the radio uses distributed computational processing across a cluster or clusters of radios in order to support the execution of advanced “cooperative” and/or “cognitive” control protocols. In addition, they use less complex, more robust waveforms designed specifically for peer to peer communication at extremely high capacity and high quality using a given spectrum bandwidth or opportunistically using dynamic spectrum awareness algorithms to recover “whitespaces”.

MANET radios also distinguish between “cooperative” and “cognitive” radio algorithms. Effective operation of a smart "cooperative" radio system in any given spectrum band requires all the associated "smart" radios operating in that band to interoperate to some level and be equivalently capable regarding basic shared frequency use cooperation and coordination. Whereas, a “cognitive” radio does not need a priori interoperability capability with the other radios in a given band providing it can detect and avoid interfering with the other radios. Cooperative radios can drive spectrum utilization to extremely high levels of data throughput saturation in a given band, whereas cognitive radios drive higher levels of foreign emitter occupancy in a given band. Both types of radios are useful and when combined together they can provide a future proof network capability for any type of licensing regime.

We encourage the FCC to foster wireless innovation in both the "cooperative" and "cognitive" generic class of radio technologies by allocating sufficient spectrum with appropriate associated spectrum use rules so industry and individuals can support new opportunistic investment in such technologies in order to accelerate innovation and market diffusion of new economic and consumer value, much as it had done earlier with unlicensed spectrum which ushered in the WiFi market innovations and values. Therefore, we propose one policy addition which the FCC can consider is the identification and/or allocation of spectrum for "cooperative" and “cognitive” radio use where the FCC can mandate technical specifications and rules for device and infrastructure cooperative/cognitive operation. These specifications and rules can be applied to the current "whitespaces" spectrum, or to newly identified spectrum that might otherwise be allocated as unlicensed spectrum but should be allocated as "cooperative/cognitive".

Section II, subsection C 4-34

Interference mitigation rules can vary greatly depending upon technology type therefore separation based solely on regulatory rules is no longer sufficient. A better approach is to move towards technology policy rules, policy engines or management information bases where the rules for mitigation can be made more flexible based on the nature of the incumbent's technology and spectrum type, and that of the secondary emitters technology operating in the incumbent's radio spectrum. The rules could be co jointly developed by the incumbent and the secondary emitters or unilaterally developed by neutral 3rd parties subject to review and oversight by the commission.

Traditional cellular systems and WiFi systems employ the concept of a master arbiter a.k.a. a base-station to manage all channel communications within a cell using a “hub and spoke”, tower based, architecture. These systems are coverage, power and capacity limited as determined by the laws of physics, i.e. “Shannon’s law” - the signaling limitation that determines the maximum bps/Hz for a given transmission from a tower to a handheld within a cell. All cell phones compete for access spectrum with all other cell phones in a given cell and therefore the base-station is unable to reuse channel spectrum once it is allocated to a particular call. The only effective means for spectrum reuse in a cellular network is to decrease the size of the cell, thereby reducing power and coverage. Thus, cellular networks are moving towards the proliferation of more micro, pico and femto cells but these types of cell systems still broadcast power inefficiently and require careful RF planning to mitigate for increased spectrum interference.

However, peer to peer, wireless, mobile ad hoc networks (MANET) take the concept of cell size reduction to its limit case where the cell phone is the cell. MANET radios coordinate amongst themselves to share spectrum and effectuate interference avoidance in ways that can increase spectral reuse for device-to-device and device-to-backhaul broadband connectivity in any given spectral regime to levels far greater than current base station and WiFi type technical architectures. Since these radios are designed to “whisper” they allow many more parallel transmissions within a given geographic area than a traditional “tower and power” cellular network, thereby increasing network tele-density and throughput per unit area. They are designed to maximize bps/Hz/m^2. In other words, a MANET radio leverages “Moore’s law” - the doubling of CPU processing capacity every 18 months to drive higher levels of distributed computational cooperation and cognition rather than be limited by the complexities of signal processing over a large area cell. Therefore, we urge the commission to set new rules or allocate additional spectrum that encourages the development of MANET radio technology which we feel would be a major driver of innovation and spectrum efficiency gains.

Section II, subsection C 5-40

We would encourage the commission to set efficiency standards, similar to fuel standards for the automotive industry, where products that serve specific spectrum licensed bands, white-spaces bands and/or unlicensed bands are required to meet higher efficiency standards over time. A good metric for establishing spectrum efficiency is the measure of Bits/Hz/Unit area (in meters). In addition, the same measure could be used to develop cost model targets and end-user service level agreements. Standards based on this metric would encourage the innovation of new classes of radio product and new network architectures.

We believe the commission has a unique opportunity starting with the rules for white spaces to define new requirements for underlay networks that are based on cognitive/cooperative radio systems that can dynamically adapt to spectrum environmental conditions or can share spectrum on an opportunistic basis through cognitive/cooperative protocols. Spectrum sensing merely detects the presence of other

interfering radios but spectrum sharing gets to the ability of the radio to negotiate with other radios to obtain even more useful spectrum slices for ad hoc transmission. These types of networks could co-exist with other types of networks and drive much higher spectral efficiency within a given band.

Section II, subsection C 5-43

We believe that databases that provide a detailed management information base regarding licensed spectrum information and rules for opportunistic access are important in the development of cognitive radio systems. A key requirement would be the development of an information model, secure access and management control to allow incumbents to register their spectrum details and rights, and to allow opportunistic users to register for secondary service. If the database is arranged as a rules based trigger system, accessible in real time for ad hoc query and spectrum access grants, then it would be possible to provide extremely dynamic spectrum access capabilities for secondary emitters without the need for strict oversight to prevent spectrum "squatting" and to provide for more equitable spectrum sharing. The more data that can be provided about the incumbent user's rights and spectrum operations the more flexible the rule making can be to help maximize the opportunistic use of the spectrum.

Section II, subsection C 5-44

The most important way to promote investment in cellular alternative architectures and new cognitive radio operation is to set aside bands exclusively for cognitive radio operation and also to define the rules for radio cooperation in such bands. Effective operation of a smart "cooperative" radio system in any given spectrum band requires all the associated "smart" radios operating in that band to inter-operate to some level and be equivalently capable regarding basic shared frequency use cooperation and coordination. Whereas, a "cognitive" radio does not need a priori interoperability capability with the other radios in a given band providing it can detect and avoid interfering with the other radios. Cooperative radios can drive spectrum utilization to extremely high levels of data throughput saturation in a given band, whereas cognitive radios drive higher levels of foreign emitter occupancy in a given band. Both types of radios are useful and when combined together they can provide a future proof network capability for any type of licensing regime.

Section II, subsection C 5-45

Unlicensed band operation is dominated by contention based media access control (MAC) protocols which leads to frequency hopping and low utilization rates within a particular frequency band due to contention resolution. An improvement would be to define radio cooperation rules that drive the development of co-channel cooperation and MAC layers that promote spectrum sharing rather than contention. This would lead to much higher spectrum utilization and bandwidth efficiency within the existing unlicensed bands, and potentially lead to cooperation between the licensed and unlicensed bands.

Section II, subsection C 5-46

New peer to peer waveforms specifically designed for co-channel/spectrum sharing will necessitate secondary emitter rules such as for white spaces or new rules for cooperative radio architectures. Note: in peer to peer waveforms there is no master/slave relationship therefore these are orthogonal radio systems which use negotiation and cooperation, and sometime cognition, to detect open spectrum or to share spectrum. The rule making has to address both cooperative and cognitive systems separately.

Section II, subsection D 1-49

The current cellular radio access networks are closed networks and don't support native IP. However, all IP radio access networks will promote open standards, applications innovation, device innovation, and accelerate development in new routing technology, cognitive radio algorithms and cooperative radio protocols.

One area of concern is the "locking" of user devices to a particular carrier or network. These proprietary arrangements undermine applications and device innovation. Another area of concern is the lack of independent standards development or the control of the standard making process by large carriers and equipment manufacturers. Standards that are not open or standards that result in a closed network architecture throttle innovation. New rules are needed for encouraging better open standards development or the more rapid creation of defacto standards.

Section II, subsection D 1-51

Wireless, mobile ad hoc, peer to peer, self forming and self healing underlay networks represent a breakthrough that can improve spectrum reuse, bandwidth data rates, lower the cost of transmission and diminish the need for spectrum hoarding. These networks use new concepts such as cooperative radio MAC's and dynamic spectrum awareness to promote co-channel sharing and very high levels of spectrum reuse. This is a major new area of research and future value creation. These types of networks can leverage opportunistic back-haul strategies such as using the same spectrum band for access and back-haul, or using all methods of back-haul concurrently for example in home DSL or cable modem, or municipal or private enterprise infrastructure, buildings, street furniture etc. through the use of low cost customer premises equipment or terminals. These concepts can find their way into existing standards or be coupled with today’s networks to increase network spectrum utilization, lower device costs, promote new application innovation and create new value sources.

Section II, subsection D 1-55

M2M devices are generally low power devices and are more likely to be densely packed and distributed in an ad hoc manner. Therefore, they naturally support the use of peer to peer networks. This is one area where underlay operating network rules would be a huge boon to capital investment and innovation for all IP radio architectures and

cooperative radio and cognitive radio development. We would encourage the commission in promoting all IP mesh networks and radio technology.

Section II, subsection D 1-57

The transition to an all IP radio access network would accelerate the development of handheld computers and transparent IP applications and services. Current cellular radio access networks are proprietary networks that stifle device, application and services innovation. The Internet Protocol is mega trend protocol that simplifies all networks, brings common concepts to applications and services development, and supports new concepts such as cloud computing and open source. Currently most IP services and applications are blocked or severely constrained from penetrating the closed radio access networks prevalent in cellular networks.

We would encourage the commission to open up new all IP radio spectrum bands where handheld radios support native IP and the access network uses a 3 layer stack with the routing layer fully compatible with the Internet and plug compatible with standard Edge Routers and standard layer 3 protocols such as OSPF and BGP4.

Section II, subsection D 1-59

We would encourage the FCC to open up new bands that define all IP radio technology, possibly combined with cooperative radio technology to promote and accelerate the creation of an all IP radio access network. This would help unleash a new era of 3rd party applications development, accelerate more open source development for wireless communication and provide for more device transparency and open application programming interfaces.

Section II, subsection D 1-60

Standards development is not independent enough since large carriers and equipment manufacturers can dominate the proceedings (sometimes in a symbiotic manner). True independence needs to be restored. De facto standards are less likely to happen since the carriers and equipment manufacturers are squeezing independent thought and innovation. This is an area for concern. New great technologies may have a tough time becoming mainstream unless promoted or vetted through a large carrier or equipment manufacturer or via an expensive "missionary" standards campaign. We would encourage new rules for fast tracking standards based on defacto standards or widespread common usage.