GOVERNMENT OF THE DISTRICT OF COLUMBIA
OFFICE OF THE CHIEF TECHNOLOGY OFFICER

Suzanne J. Peck
Chief Technology Officer

February 20, 2005

Federal Communications Commission

Experimental Licensing Branch
MS 1300E1

445 12th Street, S.W.
Washington, DC 20554

Re. Experimental Radio Station Construction Permit And License
Call Sign WD2XHO
Second Progress Report

Dear Madam/Sir:

Pursuant to the special conditions included in the grant of the experimental radio station and construction permit and license for WD2XHO (FCC File 0042-EX-ML-2004), please find attached the Second Progress Report of this experiment.

Should any clarification be necessary, please do not hesitate to contact Guy Jouannelle at 202-727-7796.

Sincerely

Robert LeGrande, II
Deputy Chief Technology Officer

The Office of the Chief Technology Officer of the District of Columbia (OCTO)

SECOND PROGRESS REPORT ON

THE CONSTRUCTION AND OPERATION OF ITS EXPERIMENTAL WIRELESS ACCELERATED RESPONDERS NETWORK (WARN)

Experimental Radio Station License - Call Sign WD2XHO

Background

The District of Columbia has recently completed an analysis of its public safety wireless data network deployment options and has determined that the spectrum and technologies on which they are based do not fulfill the pressing need of first responders today, much less the increasingly complex environment envisioned for the near future.

In order to demonstrate that affordable technologies exist today to support the critical public safety applications, the District has decided to deploy a wide area (within Washington DC city limits) broadband wireless data network that will serve as a pilot for next generation of public safety applications. The intent is to specify technology and features that best suit public safety applications requirements. To this end, the District has filed for an experimental license in January 2004. The FCC has granted this experimental license (Call sign WD2XHO) in February 2004. As the experiment will use the 700 MHz upper-band, an additional outcome of the experiments will be an evaluation of the impact of interference received from/created into TV stations broadcasting in this band.

The Office of the Chief Technology Officer of the District of Columbia (OCTO) selected Motorola and Flarion Technologies to provide, install and support a 10-site Flash OFDM broadband wireless network.
In order to allow the vendors to deliver the equipment on an expedited fashion, a modification of the experiment license was filed and granted in August 2004. The modification did consist in swapping uplink and downlink frequencies.

At the time of the filing of the previous report (August 2004), the construction of the radio sites was completed, and the optimization phase of the project was in progress.

This report first describes what spectrum is used for this experiment. It then gives an overview of the network architecture and the network measured performance. The description of the first operational experiences gained in supporting recent national events completes the report.

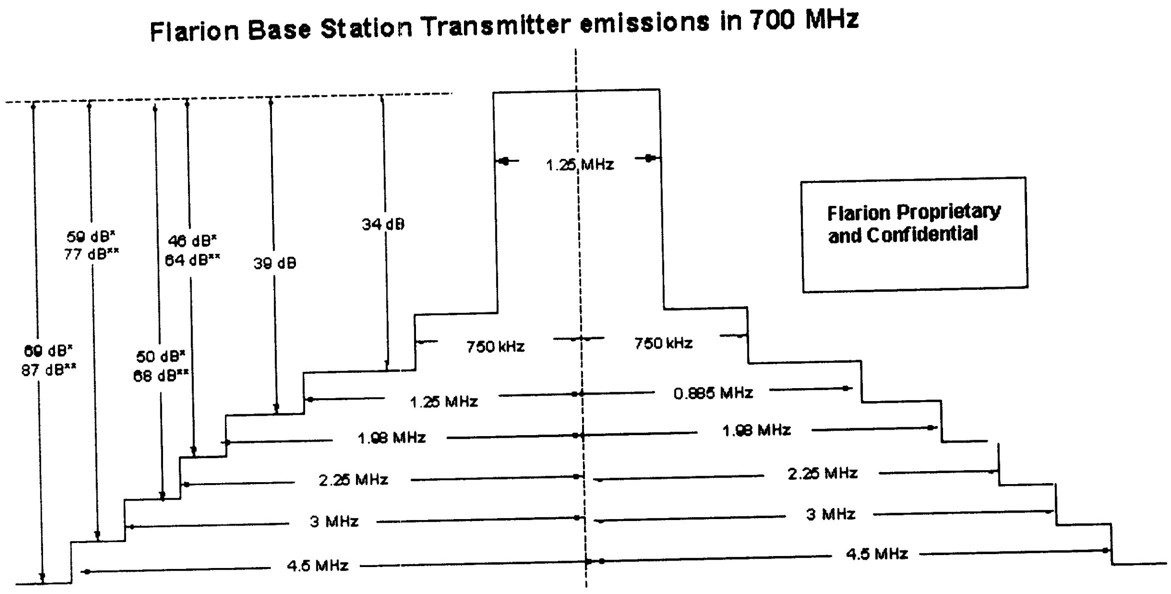
Spectrum

Figure 2 describes in light yellow the spectrum granted to OCTO through this experimental license. The WARN network will actually use one 1.25 MHz channel in each of the two 4 MHz band allocated in the TV Channel 61 (Downlink), and the TV Channel 69 (Uplink).

As the license filing described, the only TV Broadcasting station on co-channel or adjacent channel OCTO was required to coordinate with is a Maryland Public TV located in Frederick Maryland, and operating on channel 62. This channel, represented in light green on figure 2, is adjacent to OCTO's experimental downlink channel.

The actual transmitted central frequencies used by WARN are 755 MHz and 803 MHz, and therefore the Maryland Public TV channel stays about 3 MHZ apart from the transmitting Flash-OFDM station. Moreover, an additional filter was added to further protect the TV station.

Since the WARN network base stations have been transmitting, Maryland Public TV did not report any interference occurrence.



Note 1
All dB values are given on an equal bandwidth relative to signal (per Hz basis). To convert to unequal BW basis add a factor of 10Log(1.25MHz/BW).
For example to find emissions at 1.98 MHz offset in 30 kHz BW add 10Log(1.25/0.03)=16 dB, to arrive at 54 dBc
Note2
* emission value without C-block selective filter
** emission value with C-block selective filter

Figure 1: Flash OFDM Transmitting mask

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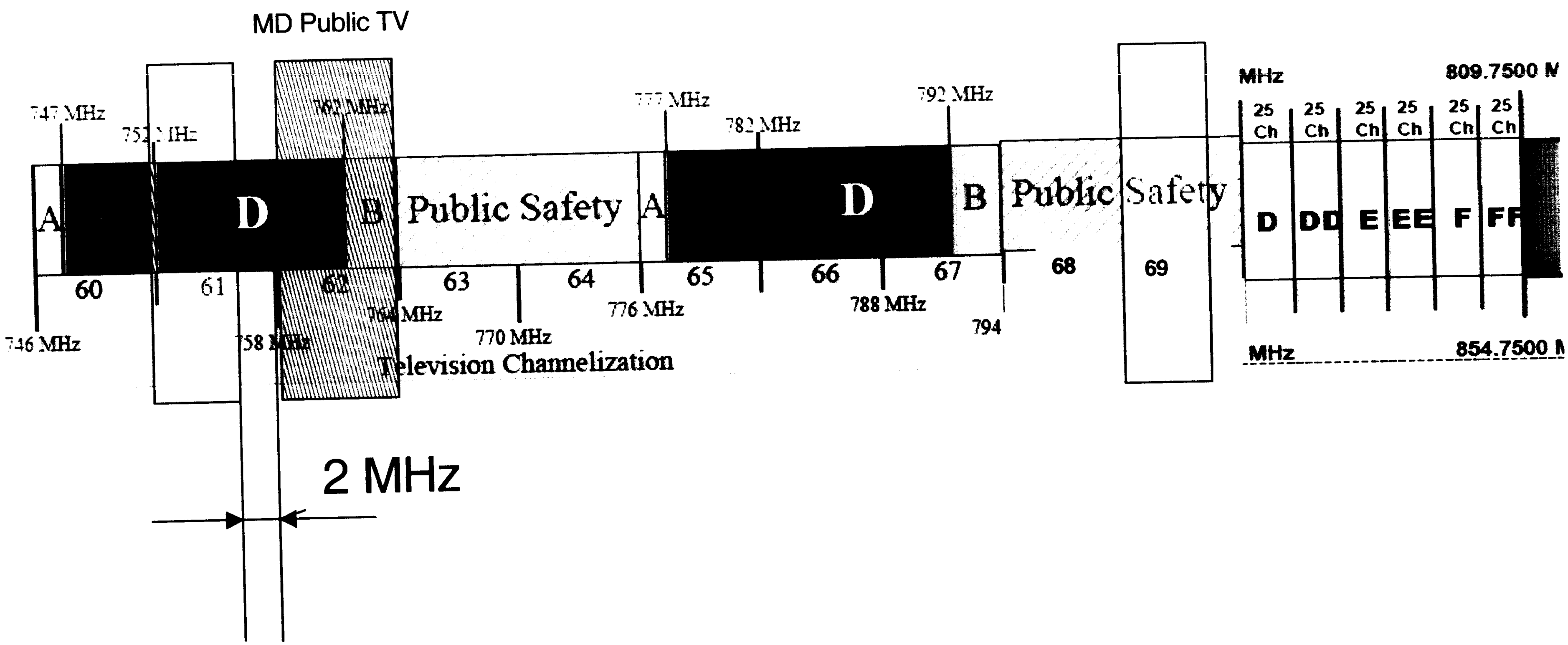
Figure 2: Experimental License spectrum Allocation



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Network Overview

Figure 3 depicts the architecture of the Wireless Accelerated Responders Network (WARN).

The network consists of ten radio sites, connected to a central node through DCNet, the District operated fiber network. The central node includes a switch that manages also the users' mobility, and also connects the users to local applications servers, and also to the internet and external agencies through the District WAN.

As figure 3 shows, the configuration of the backhaul connections, the central node switch, the AAA, is fully redundant. The switches and the AAAs are located in two different data centers. Fail-over of one data center to the other will be tested in the coming weeks.

This is an "All-IP" network. The base stations are actually IP routers that support the Flash OFDM radio interface (Radio-routers). Each terminal equipment unit is assigned an IP address, as well as each radio site and each sector.

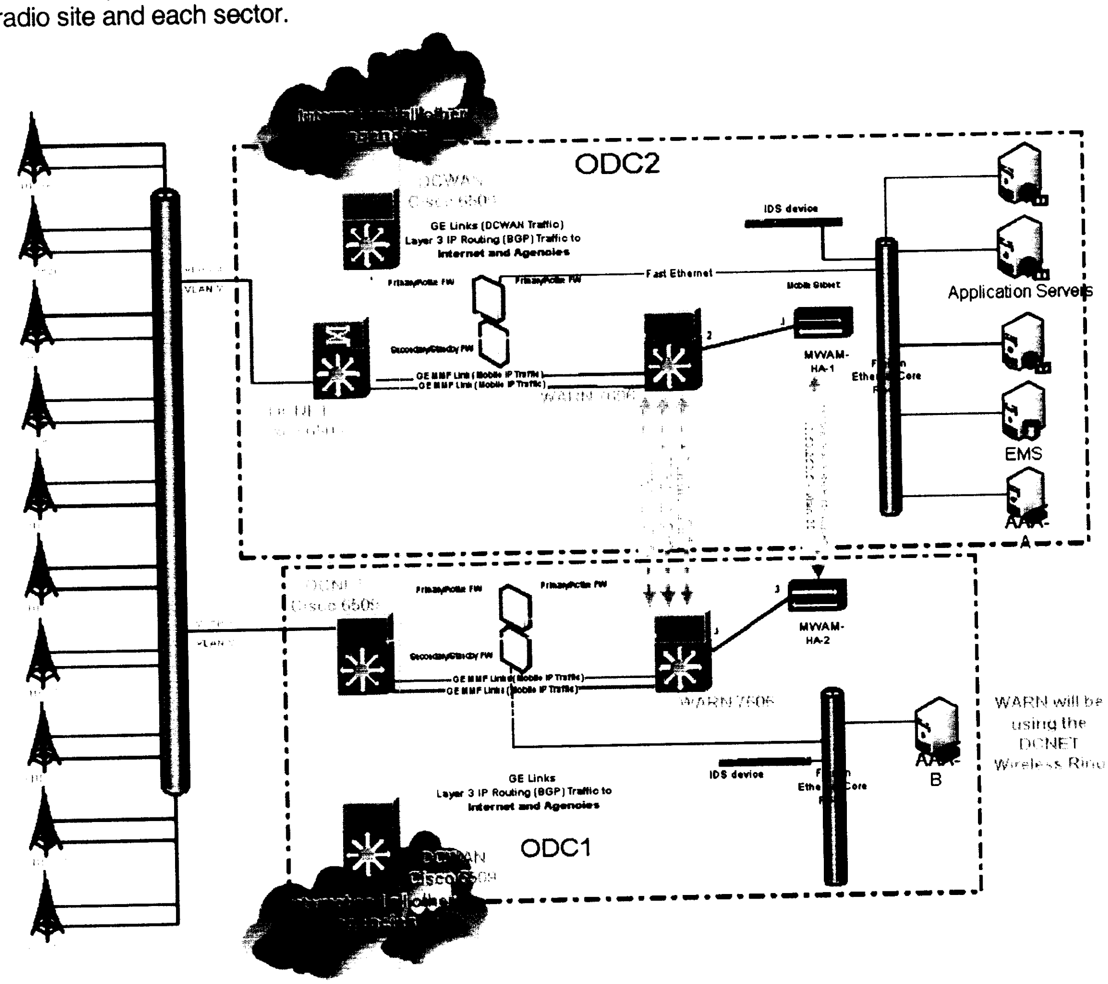

Figure 3: Network Architecture

The District of Columbia acquired 200 terminal equipment units. Those units consist in 180 PCMCIA cards that can be installed on most common PCs, and 20 PADs. The transmitted power of the terminal equipment is 250mW.

Figure 4: Flash OFDM PCMCIA card

A PAD is a small box that includes a card and an antenna, and has as well a USB port and an Ethernet port. Those ports allow for instance the connection of a desktop to the wireless network.

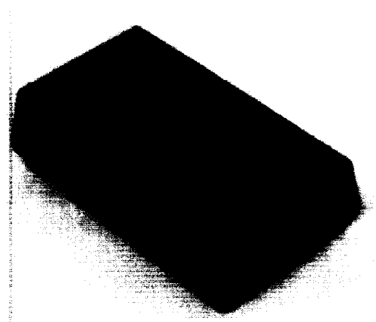

Figure 5: PAD

Each of the radio sites includes a 3-sector radio router (see figure 6). Each sector is connected to a cross-polarized panel antenna. For those sites that are buildings, the panel antennas are mounted on the side of the penthouse. The selected configuration includes receive-diversity; therefore each sector includes one transmitter, one amplifier and two receivers. The same frequency is transmitted on each sector. The amplifier transmits 20W. The panel antennas have a 12dBd gain.

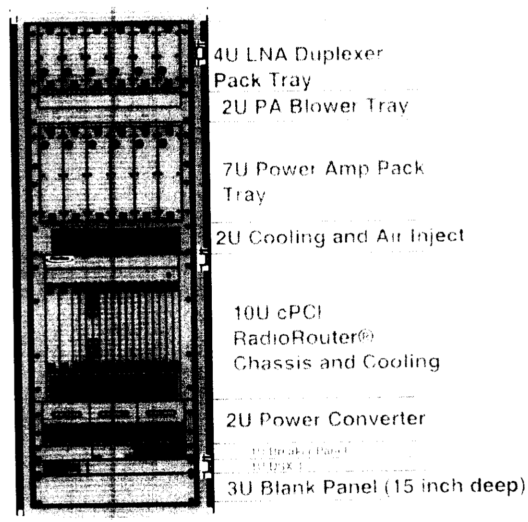

Figure 6: Radio Router

The ten WARN sites are the same sites the District of Columbia Public Safety agencies are using for their voice push-to-talk network. They all offer redundant power supply and redundant A/C units.
The radio routers themselves have redundant power units, and redundant network interface units.

Network Performance

The Flash OFDM network has a frequency reuse of one, which means that each sector is transmitting on the same frequency. Although the technology is able to separate and decode two signals on the same frequency, lower throughput rates are obtained at cell edges, where two signals of comparable strength are simultaneously received. As a consequence, the optimization of the system requires an adjustment of the antennas (tilt, azimuth) such that at the same time the coverage of the sector is maximized within its targeted area, and minimized beyond. This process is iterative, each configuration change requiring drive testing to evaluate the network's performance evolution.

The duration of this network optimization phase was longer than expected, and completed end of November 2004. The operations of the network started on December 1st 2004. The District formally accepted the network from the vendors on December 31st, 2004.

Performance Evaluation

Testing methodology:

Drive tests are performed with a laptop including a Flash OFDM card. The antenna is located inside the vehicle. This antenna configuration corresponds to an additional propagation loss of 6dB to 8dB. The laptop runs the Flarion Mobile Diagnostic Monitor (FMDM) software. FMDM monitors performance parameters such as data rates and link state for each test session. Concurrently, FMDM collects geographic location data through a GPS receiver connected to the same laptop.

Depending on the test performed, the laptop and/or the core network will run another application generating the IP traffic necessary to evaluate the parameter under evaluation.

For instance the "ping" command will be run repetitively to evaluate the network latency.
IPERF, industry standard test and evaluation software, is used to generate the maximum throughput the network can support either on the downlink (base station to mobile), or the uplink (mobile to base station). Uplink and downlink tests were run on different laptops. IPERF was configured such that data streams are generated on UDP. UDP is the protocol used for streaming video.

FMDM collects data twice a second. Through post processing the data collected by FMDM are aggregated into 400m grids. The value attached to each grid if the median value of all the instances of the parameter collected in that grid.

Results

Figure 7 represents the field strength received from the site that has the dominant pilot channel.

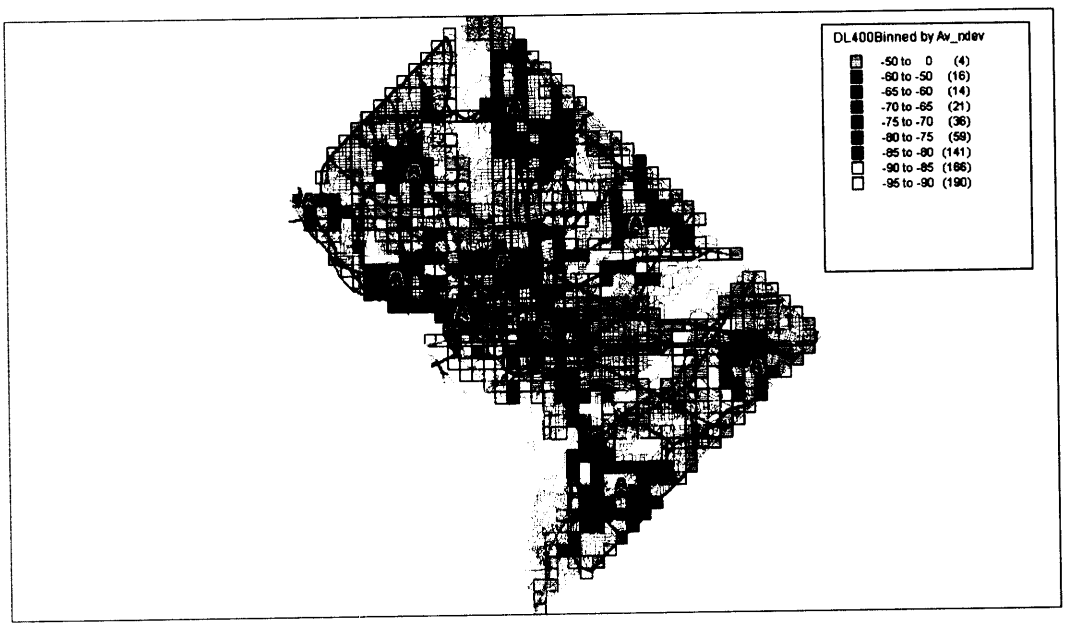

Figure 7: Measured Downlink Received level

The ten WARN sites are the same sites the District of Columbia Public Safety agencies are using for their voice push-to-talk network. However, the WARN base stations ERPs are about 6dB lower than the transmitted ERPs of the District voice network (6 dB at least). The WARN antennas are also lower (from 10 feet to 400 feet, depending on the site). As a consequence, several poor coverage areas appear on this map, although they do not exist for the voice network, or at least are smaller. The two main areas are the bed of the Anacostia River, and the Rock Creek Park (both of those areas are significant terrain depressions). Other smaller coverage holes include the vicinity of the White House, a portion of Nebraska Avenue, and some other locations closer to the city boundaries.

More than the received field strength level, the received SNR is the parameter indicates the performance of the radio link, e.g. the achievable data rate. SNR will not be satisfactory when the coverage is not sufficient, but also when the level of interference is too high. Figure 8 depicts the

downlink throughput measured throughout the city. The correlation between this map and the pilot field strength level map is high. Figure 9 shows the uplink throughput measured across the city.
The technology allows for peak rates of 2.7 Mbps for the downlink, and 900 kbps on the uplink. About 70% of the locations receive more than 300kbps in the downlink, and 60% of the locations are able to transmit 100kbps on the uplink.

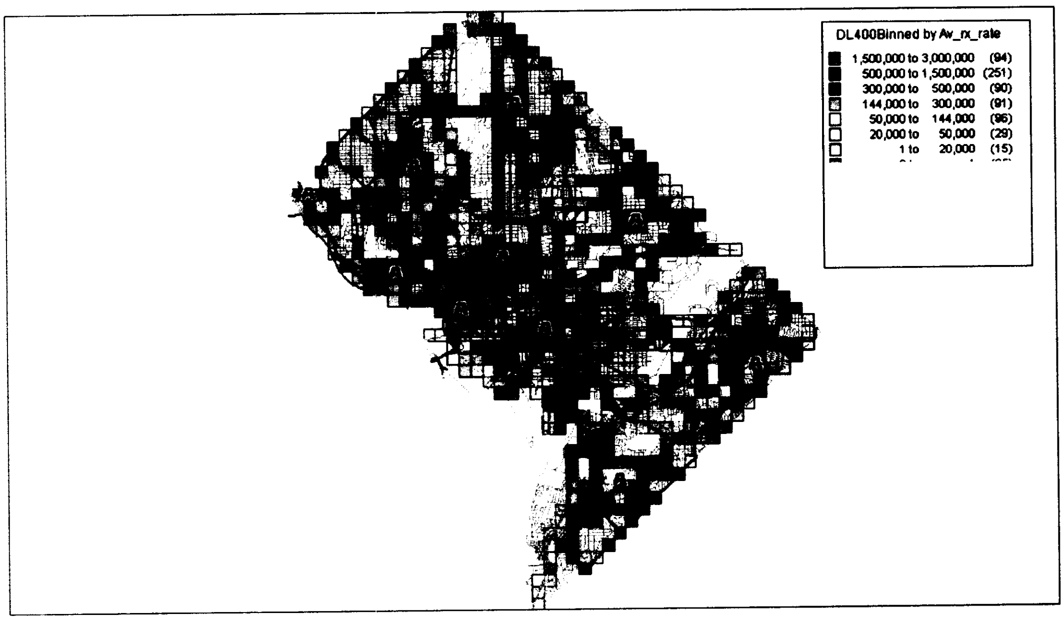

Figure 8: Downlink Received Data Rate

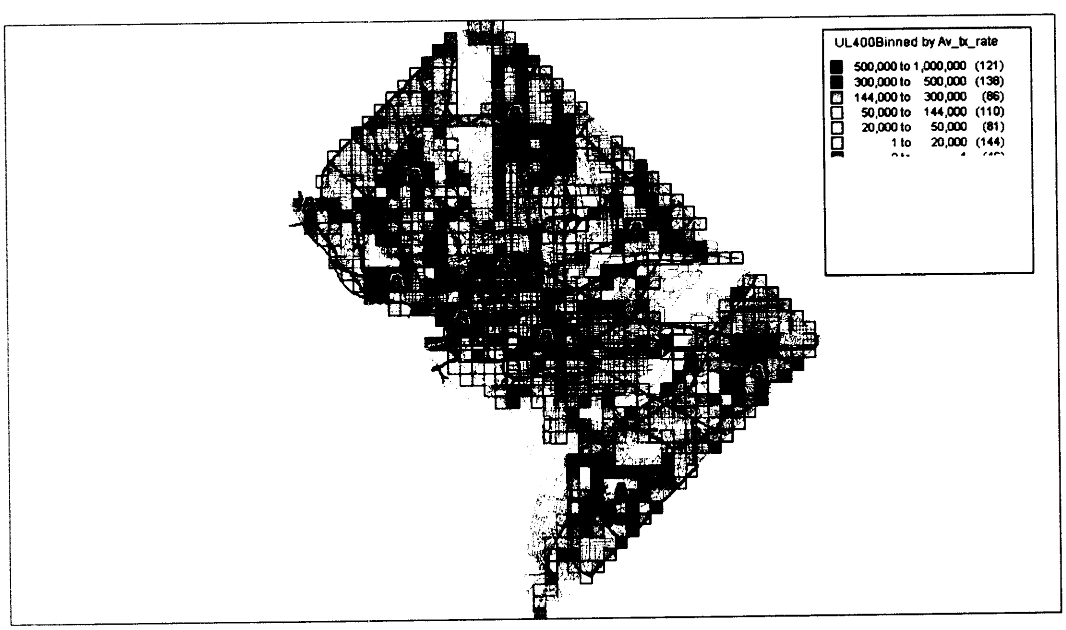

Figure 9: Uplink Transmitted Data rate

The District plans to improve the network coverage and capacity performance further by deploying two additional sites (and amend the experimental license accordingly):

- One site in the vicinity of the White House. The White House area is at the edge of three cells. As a consequence, although for the most part the received level allows for solid radio connectivity, the available throughput is limited to a range from 20kbps to 50 kbps on the uplink, and to a range from 20kbps to 120kbps on the downlink. Because of obvious reasons, this area requires a high network capacity. To support various local and federal agencies during the Presidential Inauguration, the District did deploy a temporary single sectored site (based on an STA). Following the success of the operations of this temporary site, the District intends to deploy a 3-sector site in this area for the remaining of the duration of the experimental license.
- One site in the vicinity of the RFK stadium to alleviate the coverage issues along the Anacostia River.

Other key performance parameters are summarized in the table below:

Metric	Value
Packet delay (Median single user)	30 ms
Dropped pings	2.49%
Access Failure rate (> 15s)	1.75%
System Drop rate (Session Drop and Handover Drop > 2s)	0.203/100

A key metric regarding TCP throughput performance is the delay metric as the TCP protocol matches the data rate the source sends to the destination, on the response time attached to acknowledgement messages. Therefore, regardless of the bandwidth of the channel itself, the larger the delay, the slower TCP will send packets to the destination, and the lower will be the achieved throughput.

Network Operational Experiment

The WARN pilot broadband wireless network was accepted from Motorola/Flarion on December 31, 2004. Since that time, 57 WARN PC Cards (including 10 backup cards) were distributed to users in MPD, US Secret Service, DC EMA, DC F/EMS, US Park Police, WMATA, and OCME. The network uses 11 transceiver sites[1], interconnected to the two District data centers via an independent DC-NET ring. This interconnection at the data centers provides access through DC-WAN to other District agencies and the Internet for WARN users.

Since then, WARN was able to support those agencies in particular during two major events: The Presidential Inauguration, and the State of the Union Address.

During the Inauguration, users provided their own applications with one exception. Most users planned to run standard web based applications (e.g. web based news) with the exception of two agencies. One deployed an uplink video system that enabled command centers with a view of streaming mobile

[1] Includes 10 sites from the existing radio network and a temporary site near the White deployed for the Presidential Inauguration support

video signals. Another agency worked with OCTO Wireless to deploy Motorola's Greenhouse software, that provides bi-directional audio and video with the intention to stream video from a Command Bus and an additional cruiser to its Operational Control Center. Other fixed video streams were streamed from this Operational Control Center to other locations in the metropolitan area using a satellite. The District City-Wide IT Security and the DC WAN organizations made network modifications to enable all the user and administrative applications needed to provide the end benefit to the users.

During the State of the Union Address, the main application deployed was the uplink video system.

During both events, the generated traffic was in the downtown area of the District, between the surroundings of the Capitol, and the neighborhood of the White House. Three sectors of the WARN network cover this area. As figure 10 shows, the temporary sector deployed for the occasion tremendously improved the available throughput in the White House area.

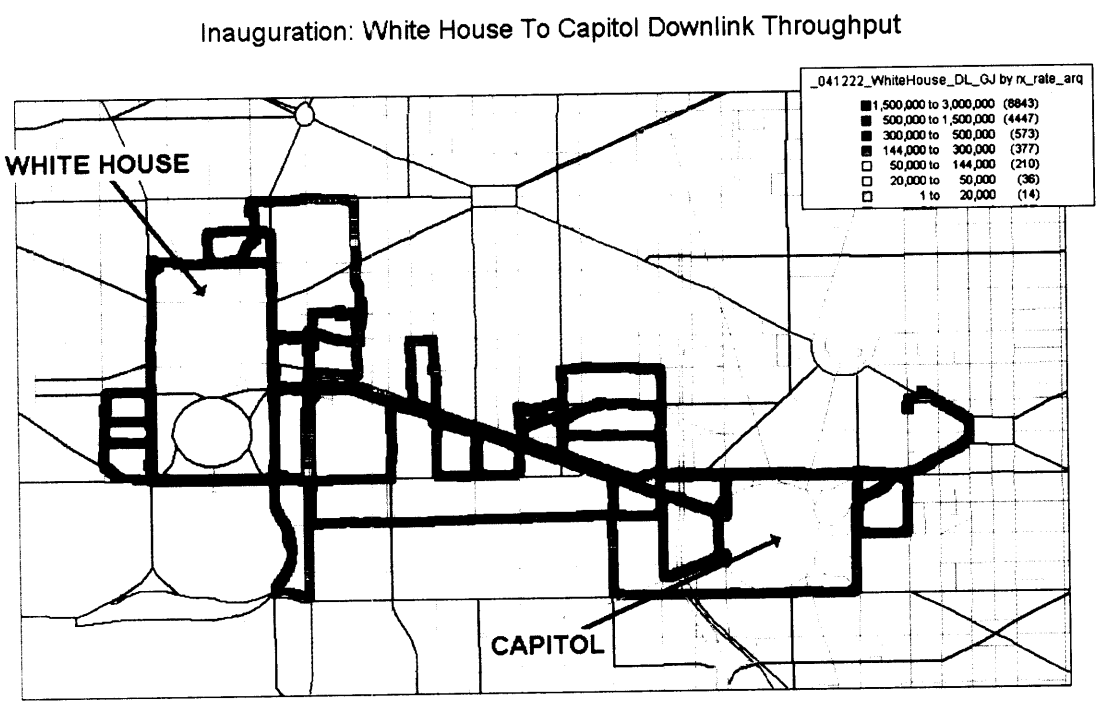

Figure 10: Inauguration area: Downlink Throughput

The statistics collected during those events show that very small traffic was carried on other sectors. Fig 11 and 12 show the load of the sectors that carried most of the traffic. In this case, percentage load corresponds to the maximum percentage of usage of the radio resources. This does not necessarily correspond to the maximum of throughput as it depends on the location of the mobiles. The charts show that the uplink resources were fully used during most of the event, as up to six video-camera-equipped vehicles were cruising, and up to eight uplink video feeds were transmitted.

This specific video application used motion jpeg as a coding scheme. During the event, on the average, 3 to 4 frames were sent per second, which correspond to maximum data rate of 400kbps each.

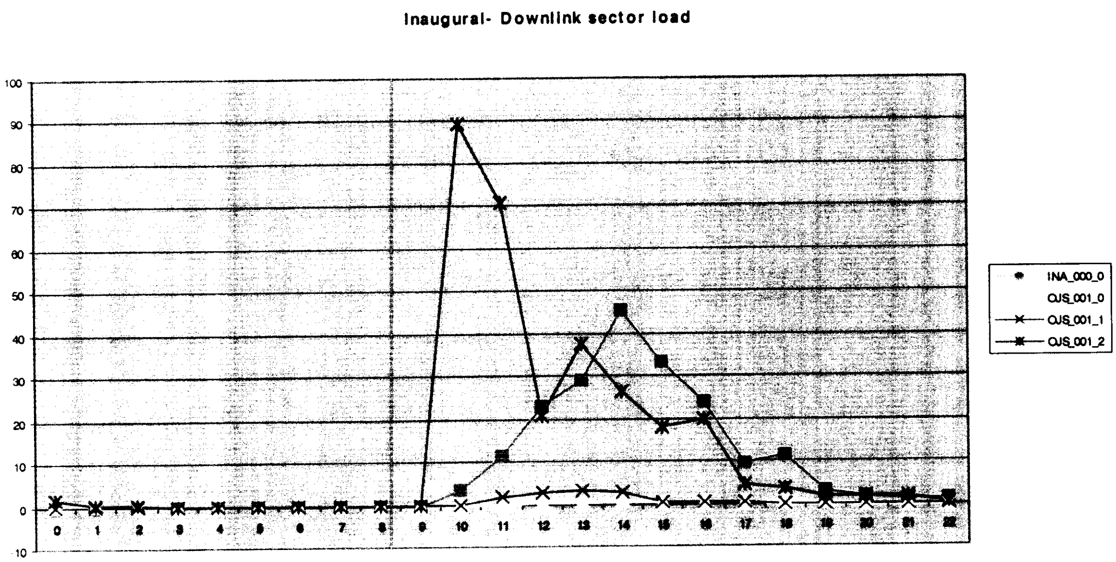

Figure 11: Inauguration: Downlink sector Load

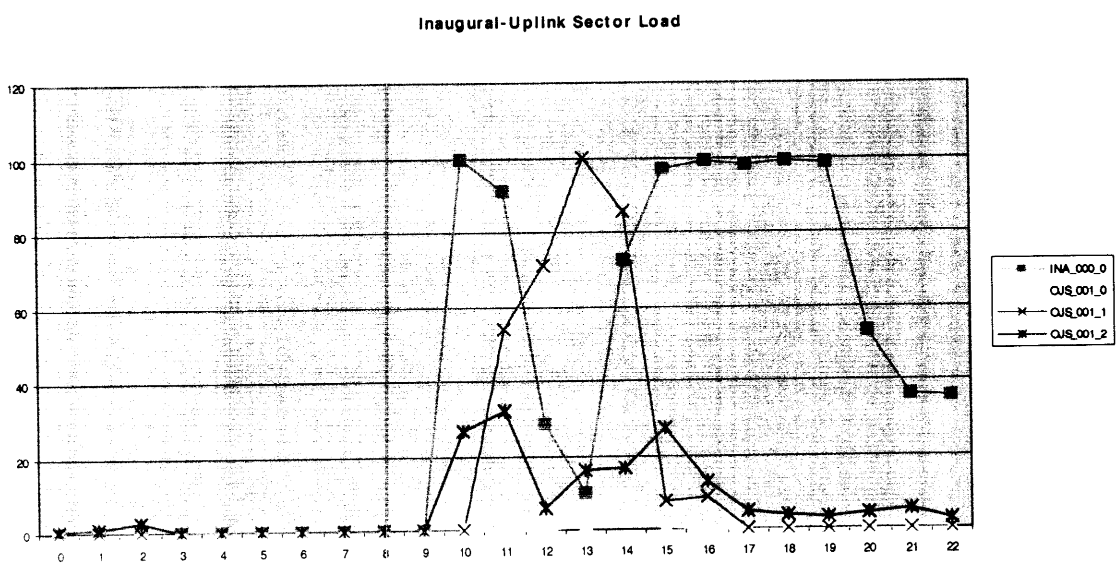

Figure 12: Inauguration: Uplink sector load

The table below summarizes the total volume of traffic carried on the network the day of the Presidential Inauguration.
The units are Bytes. This shows that more than 5 GB were transmitted on the uplink (mainly video from cruisers), and 2.2 GB were transmitted on the downlink.

	Uplink Traffic	Downlink Traffic
Agency 1	789,023	2,107,863
Agency 2	16,552,966	24,493,503
Agency 3	243,514,719	336,609,143
Agency 4	20,119,138	44,534,270
Agency 5	34,331,087	412,230,694
Agency 6	4,765,773,330	24,788,760
Agency 7	99,914,071	1,415,030,776
TOTAL	5,180,994,334	2,259,795,009

The use of the network for the State of the Union, the same applications were operational. However a lesser number of units were deployed, and the event was shorter (few hours versus a full-day), resulting in less total carried traffic (see figures 13 and 14).

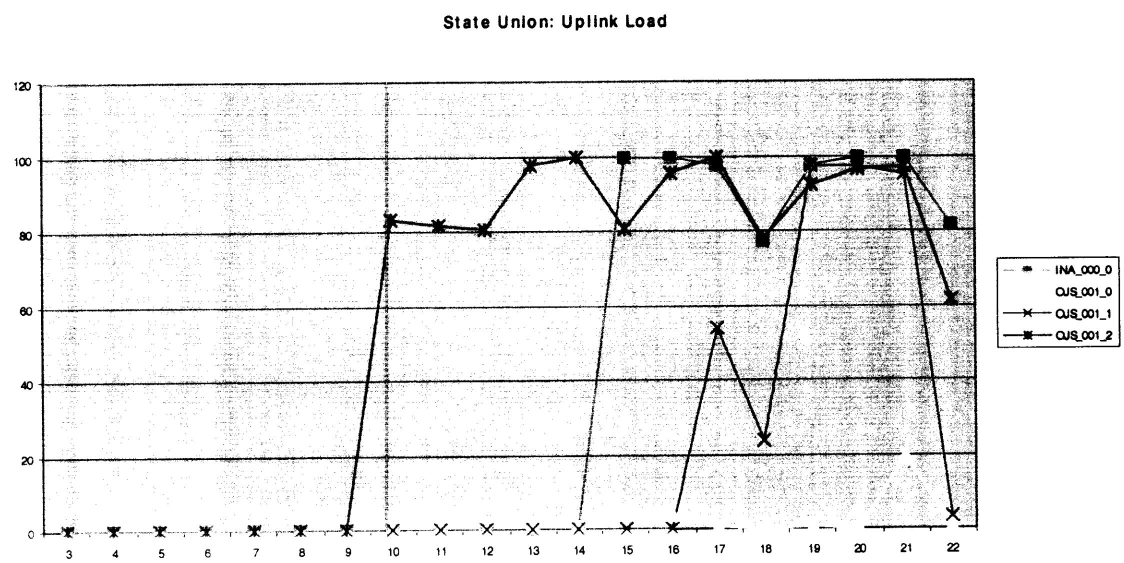

Figure 13: State of the Union: Uplink Sector Load

State Union: Downlink load

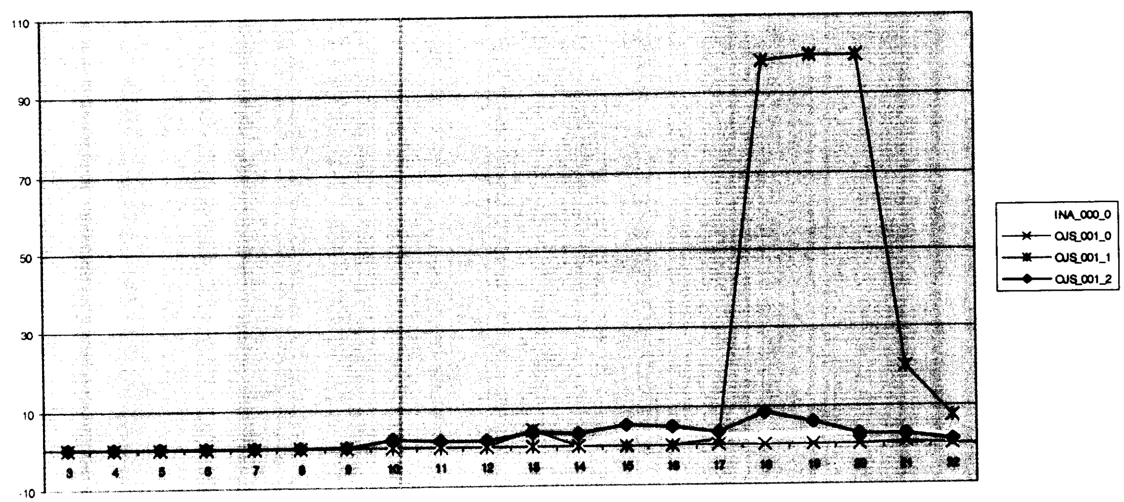

Figure 14: State of the Union : Downlink Sector Load

The total traffic carried during the State of the Union address was 1.2GB on the uplink and 366 MB on the downlink.

Agency	Downlink	Uplink
Agency 1	314,650,316	9,486,741
Agency 2	4,929,808	5,420,722
Agency 3	925,374	476,321
Agency 4	20,230,740	24,525,651
Agency 5	25,030,387	1,229,317,263
Agency 6	637,728	489,665
Total	366,404,353	1,269,716,363

Next milestones

In the coming months, OCTO intends to further improve the performance of the network and the service to its first responders.

The deployment of two additional sites will allow an improvement of coverage and capacity of the network in strategic areas.

The execution of additional tests of some of the technology features (implementation of QoS, multicast, etc.) will allow the District to optimize the use of the capacity of the network.

The rollout of new applications will allow to evaluate how much the WARN network can enhance the capabilities of our first responders.