



Connecting Land-Based Networks to Ships

Lt. Panagiotis (Panos) Chatzigiannis (Hellenic Navy)
LtCol John Gibson, USAF (Ret)
Dr. Gurminder Singh



Introduction

- Enable Navy littoral ships to communicate with shore networks
 - Littoral ships operate within a few miles of shores
 - Limited space for antennas
 - Satellite links more expensive and less capable (GEO – low data rates) or require complex antennas (MEO – tracking needed)
 - Ship near shore may use alternate methods of communicating with the shore network, which are typically faster and cost less than satellite-based services.
- Evaluate the various methods available in terms of range, bandwidth, and quality of service (QoS) by conducting experiments in Monterey Bay, CA.
- Focus on COTS technology



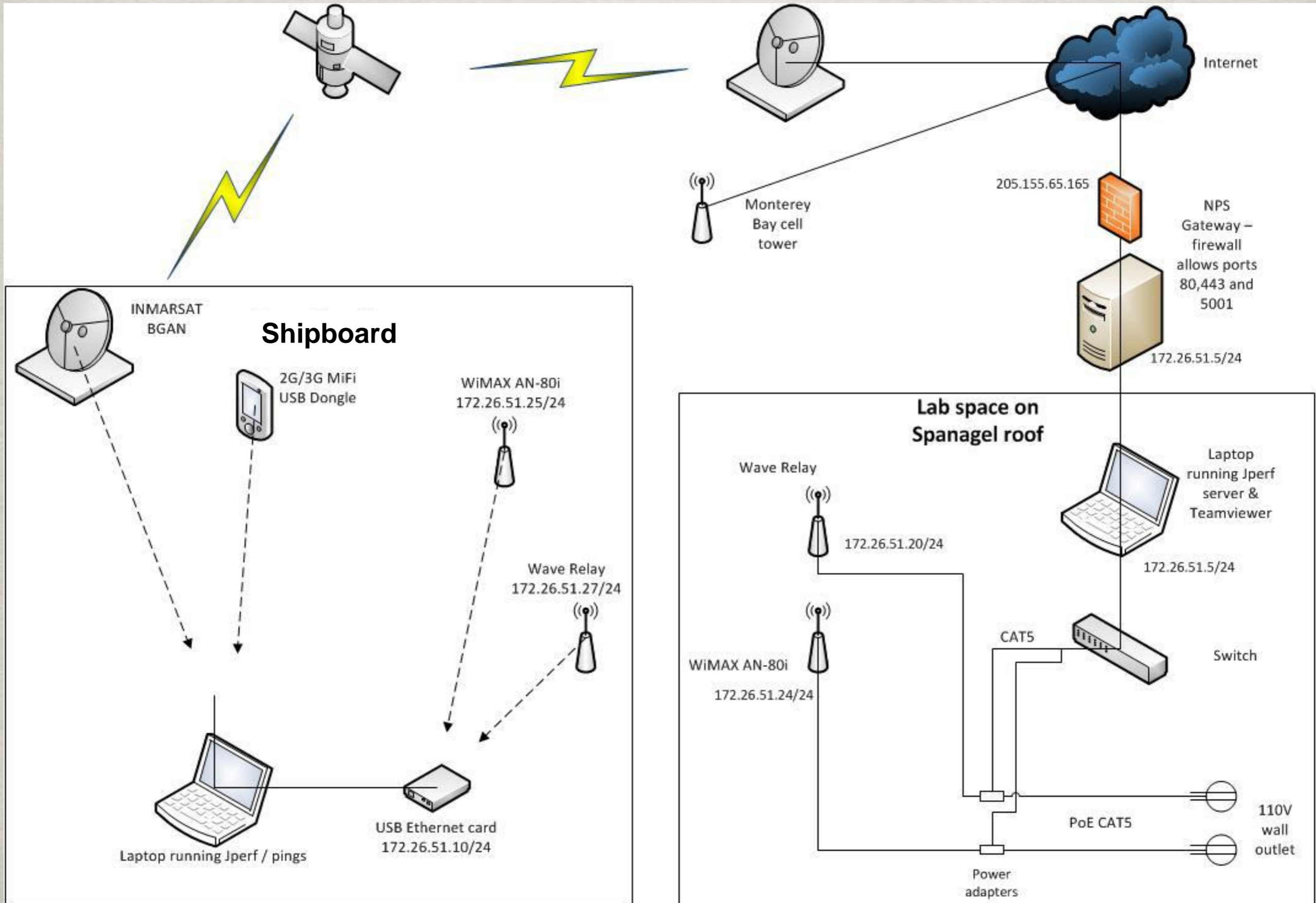
- Help military ships operating in coastal waters integrate into military networks
 - Participate in the generation and maintenance of a common situational awareness between the ashore elements and the afloat elements.
 - Enable the ship's personnel access to functionality that they would normally have only if the ship was docked.
- Compare network access through WiMAX (IEEE 802.16), 3/4G WAN, satellite communications, and a wave relay wireless LANs.

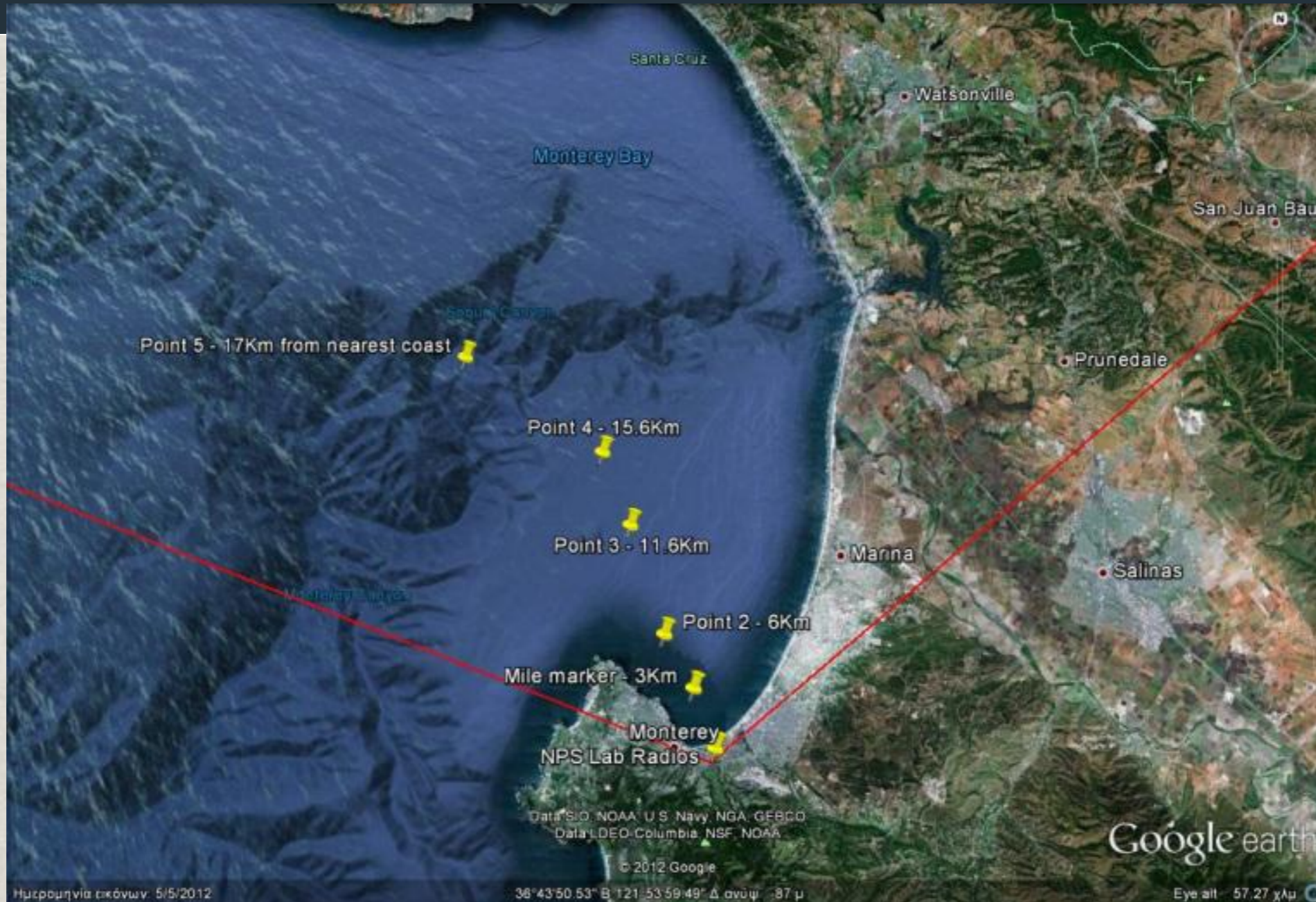


Some Current Examples – COTS Technology in Use

- *WiMax - Singapore's Wise Port* - wireless broadband connectivity to Singapore's coastal waters, up to a range of 15 km (about 8 nautical miles).
 - Enabled ferries, as well as arriving and anchored vessels, to access the Internet to send engine reports to shore, receive schedules and instructions, submit documents to the terminal operators, contact their logistics providers, and access tidal information etc.
 - Islands and offshore oil platforms are also potential customers to the system
- *WiFi - Floating Area Network* - enable ships at sea to communicate with each other using long-distance 802.11 antennas, having a line-of-sight range.
 - *Seattle ferries* - 802.11 wireless connectivity to passengers waiting on the ferry terminals and aboard the ferries while in transit.

Experimental Design





- Experiments conducted in the Monterey Bay Area
 - WiMAX and a Wave Relay on shore at NPS
 - Omni-directional WiMAX and WaveRelay antennas on research vessel
 - Cellular-enabled WiFi Hot Spot on research vessel



Comparison of Published Specifications

	WiMAX	Wave Relay	3G cellular	Satellite
Maximum Range (km)	80	24.3 (40MHz channel), 52.5 (20Mhz channel)	35	Virtually unlimited
Maximum throughput	90 Mbps	27Mbps (TCP), 37Mbps (UDP)	7.2Mbps (HSDPA commercial user devices)	464Kbps
Encryption	AES-128, AES-256	AES-CTR-256 with SHA-512 MAC		
Channel size	40Mhz	40Mhz		
Max Tx power	25dBm	28dBm (civilian version), 33dBm (military version)		
Antenna Gain	16dBi (120° sector), 9dBi (omni)	14dBi (120° sector), 5dBi (omni)		
Frequency	5.8Ghz	2.3-2.5Ghz and 5Ghz	850Mhz, 900Mhz, 1.8Ghz and 1.9Ghz	



Results - WiMAX

- Experimental results much different than anticipated.
 - WiMAX theoretical range - up to 50Km; we observed an intermittent, unstable, and unreliable connectivity at 6Km!
 - Possible reason –
 - use of a 120-degree sector antenna for the fixed radio (with a 16 dBi gain) and
 - an omni-directional antenna for the mobile radio (with a 9 dBi gain).
 - This setup was intentional –
 - A sector antenna for the fixed station to cover as much area as possible, since the ship won't be at a specific bearing at all times.
 - Also the ship will be moving about and can change its heading at anytime.
- Performance subject to weather conditions – Monterey Bay is often foggy.



Results – Persistent Systems Wave Relay

- Performed better than WiMAX in our context.
- Max usable range more than 17Km (vs stated 24Km)
 - Data rate degraded but still good enough for applications, like web-browsing, mail, or small file transfer, with the same antenna constraints.
- At 11Km, bandwidth is around 0.5Mbps, which can support real-time video applications.
- Ship could stay at the edge of the coverage sector if it just needs to send some e-mails or photos, or move closer to the shore for more bandwidth-demanding applications.



- Led the way in terms of bandwidth performance but not RTT.
- Even at distant locations, more than 17Km away from the nearest shore, they still have 0.6Mbps throughput.
- Average RTT much higher compared to Wave Relay,
 - 3G RTT must account for the cellular system-to-Internet routing of the packets back to the NPS location,
 - May not be as useful for real-time applications.
- Since 3G is a commercial network, may not be suitable for sensitive applications.
 - Encryption not military grade
 - Network can't be organically managed as may be needed



Results – INMARSAT

- Results as expected
- Throughput of 255Kbps (less than the advertised 432Kbps)
- RTT is very large, mostly over a second
 - Was expected since the connection not only goes through the 500ms GEO satellite propagation delay, but also through INMARSAT company headquarters in the United Kingdom.
- Despite performance and cost issues, most useful for beyond LOS operations.
- Like cellular, may not be suitable for sensitive applications.
 - Encryption not military grade
 - Network can't be organically managed as may be needed



Conclusion

- If you have been paying attention, then you know what to do.
- If not, take two aspirins and call in tomorrow.



Result Summary

	WiMAX	Wave Relay	2G/3G cellular	Satellite
Maximum range	6Km	17Km	>17Km	-
Throughput at 6Km	138Kbps, 12ms RTT, 69% packet loss	820Kbps	-	255Kbps, 1527ms RTT
SNR at 6Km	-	38dB	-	
Throughput at 11.6Km	-	483Kbps	-	
SNR at 11.6Km	-	17.89dB	-	
Throughput at 15.6Km	-	167.39Kbps, 47ms RTT, 9% packet loss	-	
SNR at 15.6Km	-	14.66dB	-	
Throughput at 17Km	-	-	686Kbps, 137ms RTT	