NETWORK-CENTRIC APPLICATIONS AND TACTICAL NETWORKS

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Tactical Networks

- If you have ever worked with Tactical networks
  - Quickly realize
    - Do not match wired networks in
      - Throughput
      - Reliability / packet delivery (loss) / connectivity
      - Are highly mobile
  - They are the mainstay of warfighter connectivity
    - Recent experience shows the benefits, and cost, of having (or not having) reliable tactical networks
      - Knowing where your friends are is very important in fast paced hostile environments
        - » Prevents you from being fired on, allow you to fire / react more quickly
- Nearly unimaginable we would consider a fast paced large or medium scale military action without the deployment of tactical data networks
  - They are, to an every increasing degree, becoming a critical part of modern warfare

Tactical Networks

- Mostly discussing mobile networks used by warfighters on the pointy end of the spear
  - Wireless, mobile, ad hoc, often air borne relay based, on-the-move, over-the-horizon
- Not discussing Command Post large scale SATCOM type configurations
  - If it arrives on 10s of trucks and takes days to establish, it doesn't meet the threshold for this discussion

Tactical C2 Apps

- Are the critical component that bring functionality to the applications
  - No one cares about communications without C2
  - However, you can't "command and control" without communications
- At user (warfighter) level these systems have always been linked
- GCCS, C2PC, FBCB2, AFADTS
  - Well know "C2" applications in "common" use by warfighters
    - All used in Iraq Freedom
  - None define a communication path
  - All are intended to operate over "network of opportunity"
    - In many cases, they simply don't
      - Or at least have lots of room for improvement

Network & Applications

- System approach – combination of Apps and network is the “problem”
  - To date we (developers of apps and networks) have done poor job of recognizing and adapting to limitations of the other
  - Result has been rather marginal performance of these systems
    - Rarely do warfighters believe C2 systems meet their requirements
    - Even when they believe C2 systems meets requirements – they “blame” comms system for poor performance and resultant poor C2

Network & Applications

- “We” must advance the current state of the art
- Next big strides will be made when application developers accept and compensate for “deficiencies” in tactical comms
- Tactical comms will improve, but
  - They will never be ubiquitous
    - There will be total comms outages and sometime they will last for minutes or 10s minutes
  - They will never have enough throughput
  - They will never have packet delivery approaching wired networks

Network & Applications

- Tactical networks currently have and will (likely) evolve to support
  - Packet loss on the order of 20-40%
    - Over a several minute average
  - Throughput on the order of 10s Kbps to/from each “major” node
    - Some key nodes will be higher, perhaps much higher, but C2 apps should be designed for the lower end, not the extremes
  - Total comms outages from few minutes to 10s minutes pretty “routinely”
  - Be very heterogeneous in nature
    - Don’t try to model any one radio / network approach it isn’t necessary
    - Instead, focus on basic “services” network provides
      - Build C2 applications tolerant of the services that can be provided

We Are Comms Guys

- Realize some in comms community disagree with our summary performance assessment, however
- We have lots of data to suggest we are “reasonably” accurate
- See no major “break through” in technology that will substantially change them
- Believe them reasonable enough to encourage their use by application developers
  - Guarantee they are much closer to reality (past, present, future) then developing on a wired Ethernet

ELB ACTD Architecture

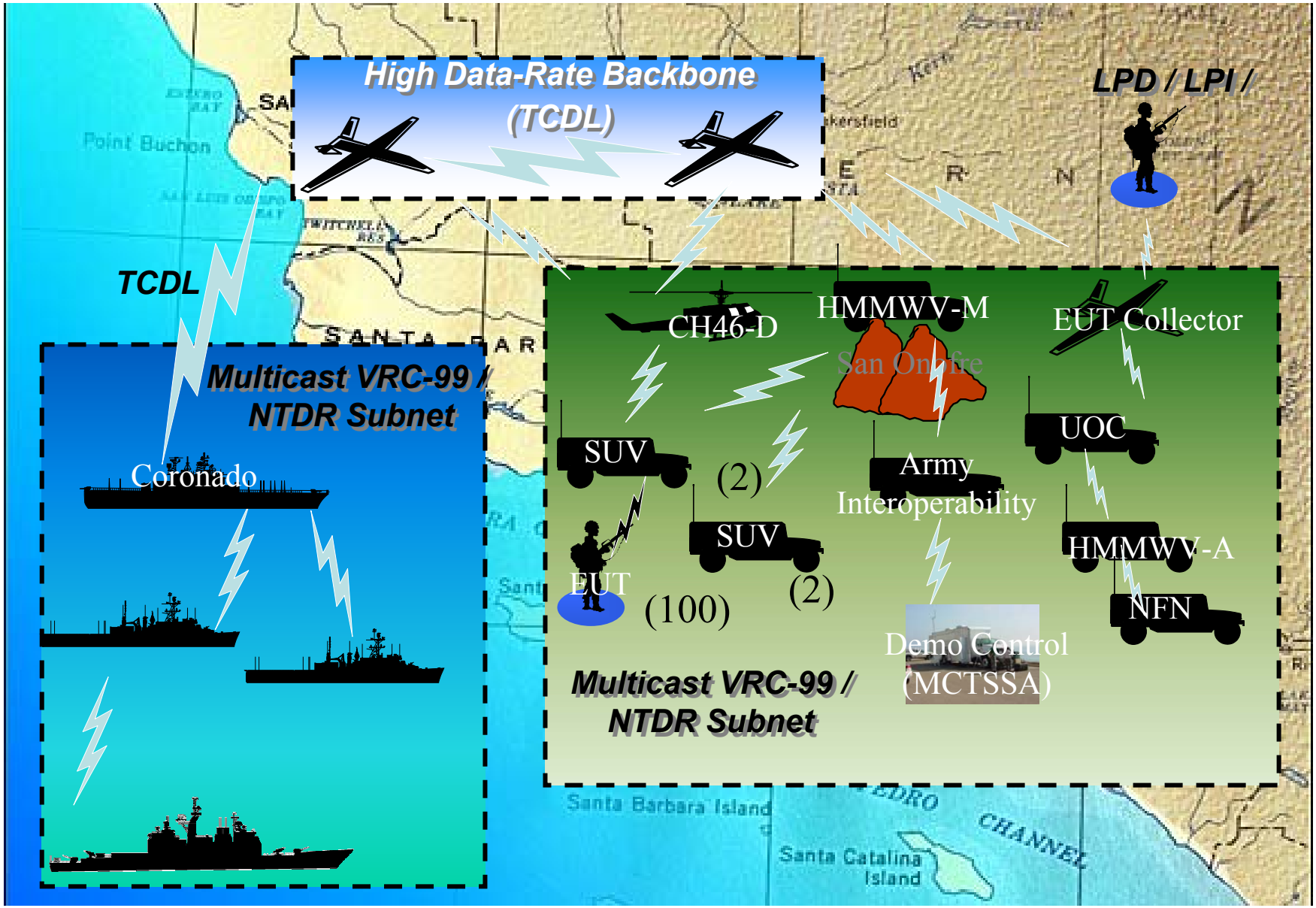
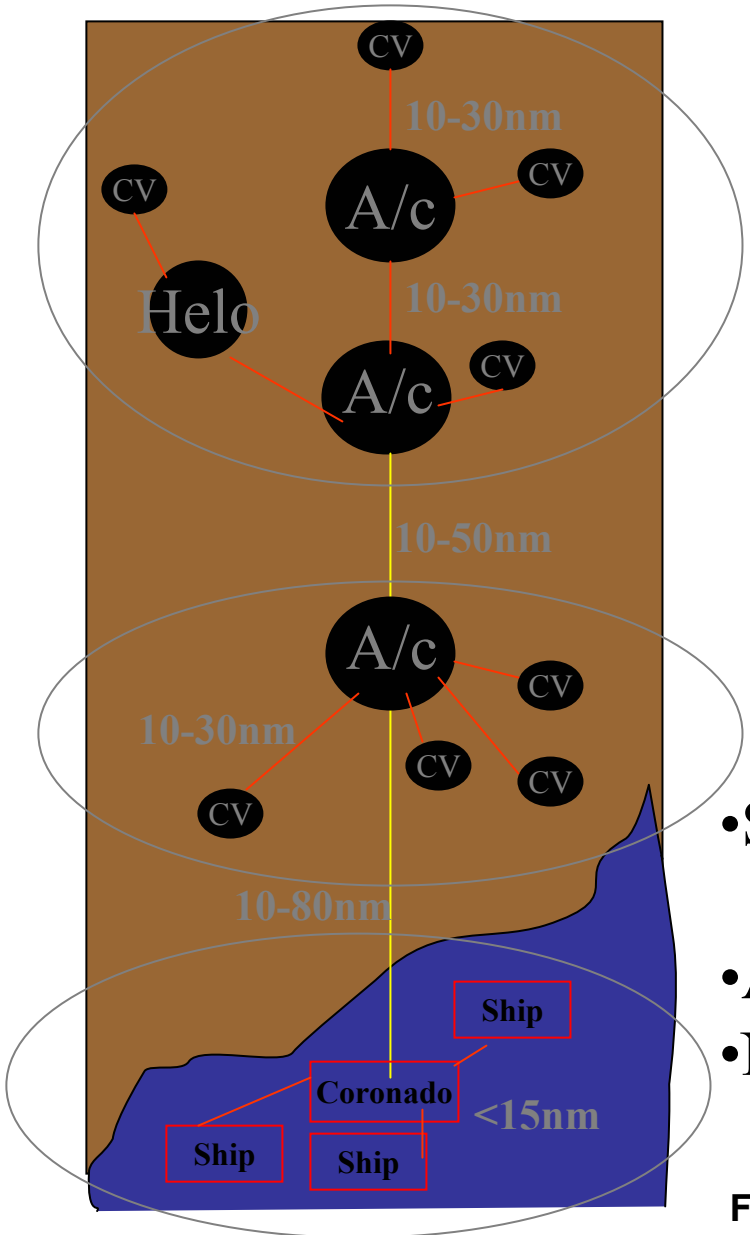


Figure 1

ELB ACTD Technical Architecture

JOA 200nm x 100nm



CV Tier 1 – Wavelan "subnet"

Tier 2 – VRC-99 NTDR

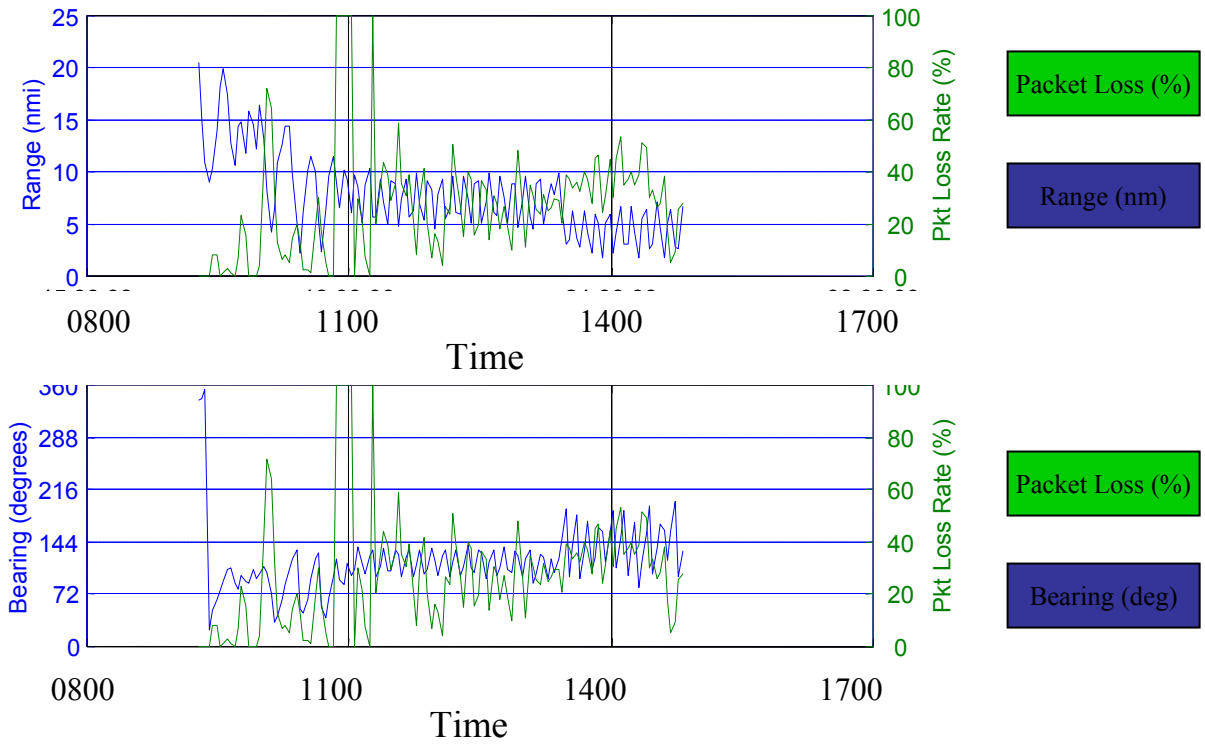
Tier 2 "subnet"

Tier 3 – TCDL (pt. pt. link)

- Seamlessly interconnected via Routers
- All nodes highly mobile
- Network dynamically reconfigures in real-time

Figure 2

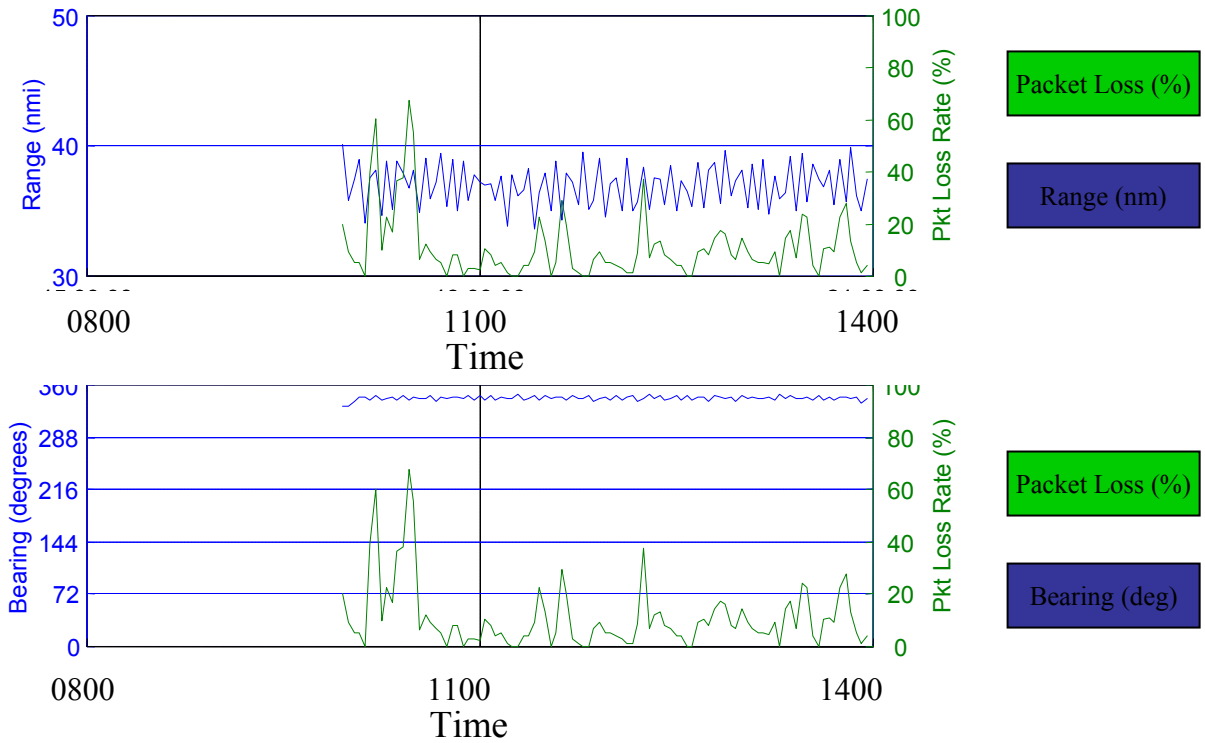
June 19, SYSCON truck to 79N



Overall packet loss 27%.

Figure 3

JUNE 21, 62M to the SIL



overall packet loss 13%

Figure 4

02/24/2000
WaveLAN Testing
Racetrack
Bot 4 Patch, 9,000 ft, 62M

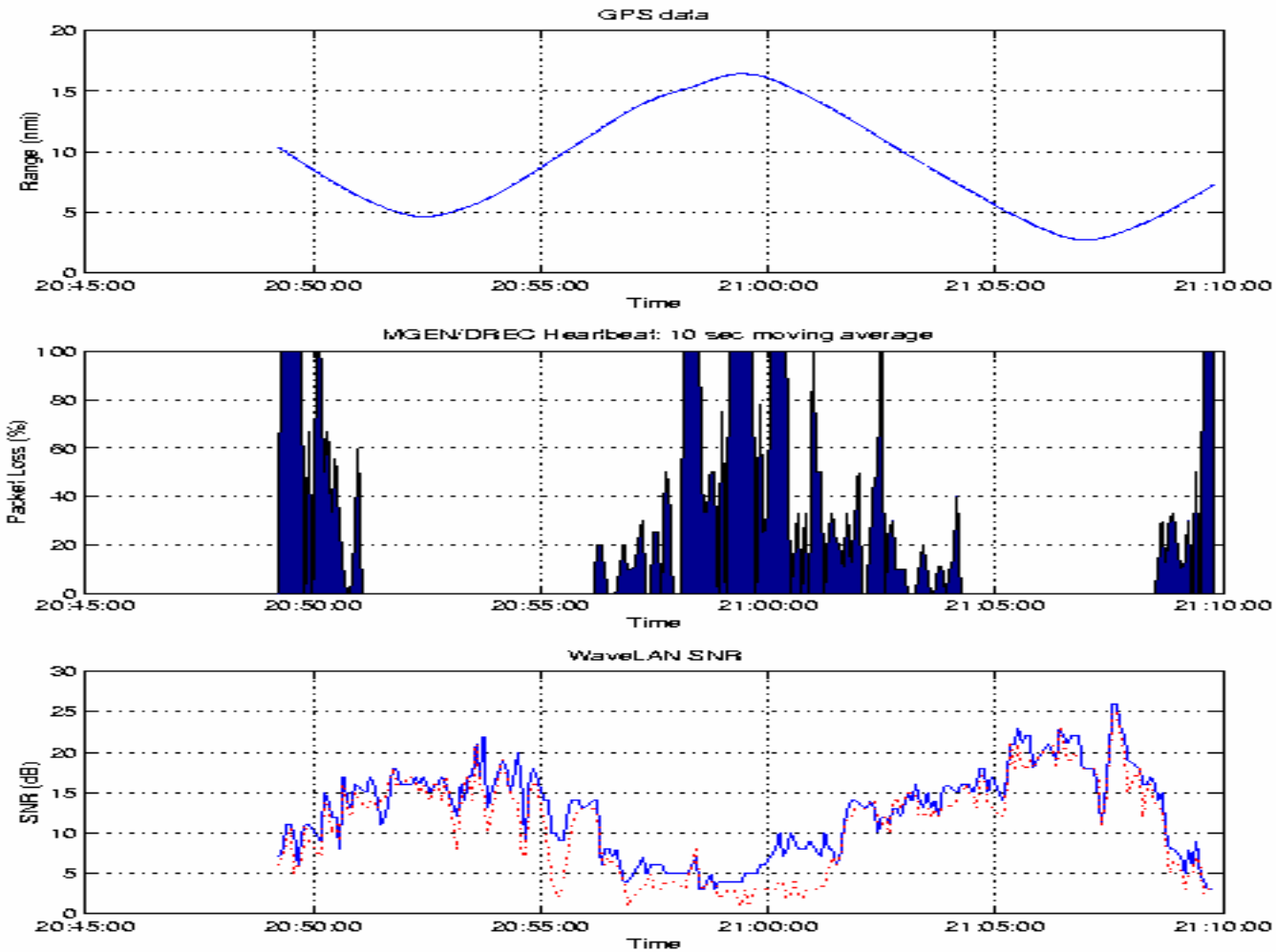


Figure 5

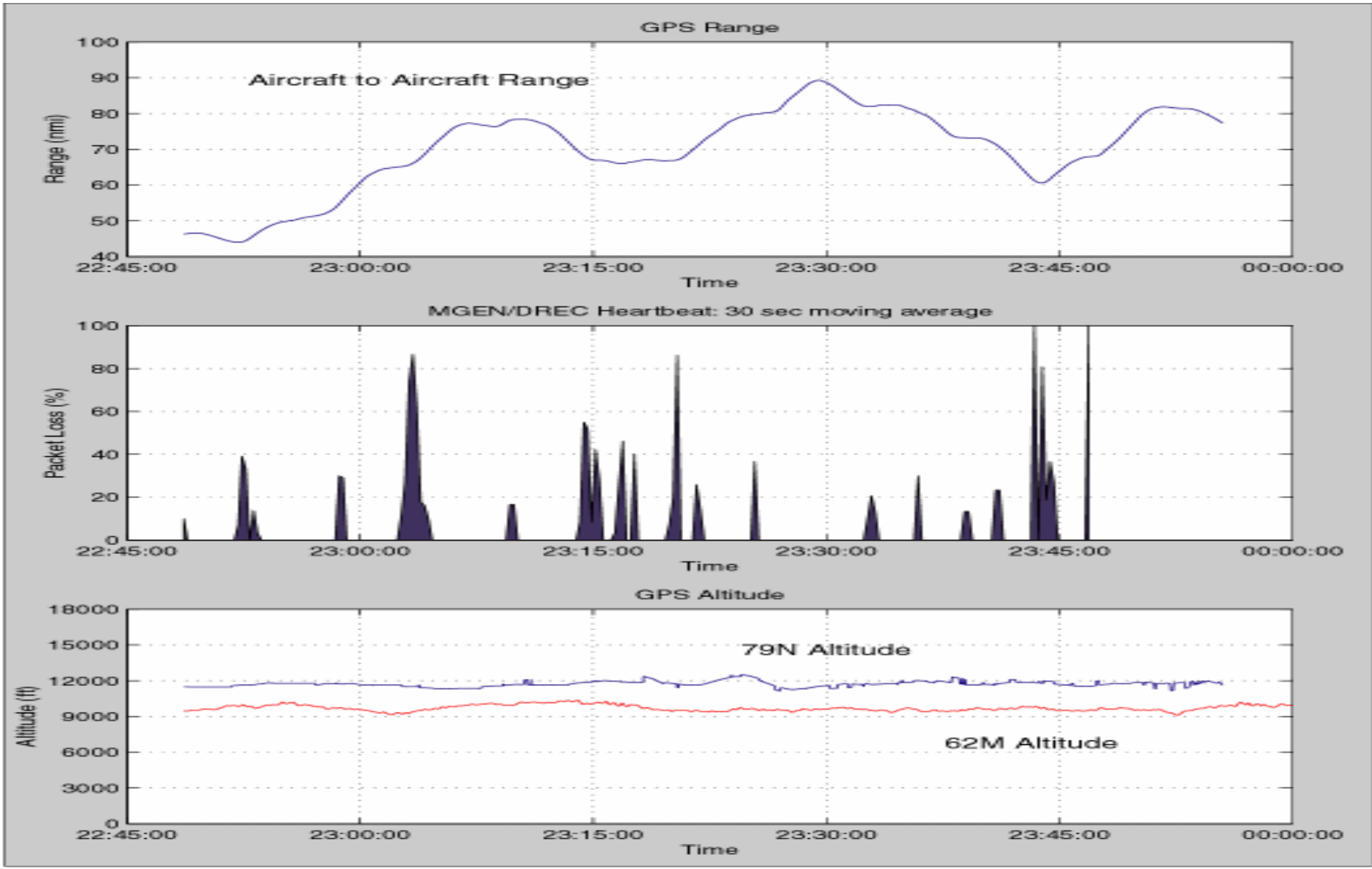

GPS Range
Aircraft to Aircraft Range
Range (nmi)
100
90
80
70
60
50
40
22:45:00
23:00:00
23:15:00
23:30:00
23:45:00
00:00:00
Time
MGEN/DREC Heartbeat: 30 sec moving average
Packet Loss (%)
100
80
60
40
20
0
22:45:00
23:00:00
23:15:00
23:30:00
23:45:00
00:00:00
Time
GPS Altitude
79N Altitude
62M Altitude
Altitude (ft)
18000
15000
12000
9000
6000
3000
0
22:45:00
23:00:00
23:15:00
23:30:00
23:45:00
00:00:00
Time

Figure 6

Ramp, 1000 byte Pkts, Air 20 nm, Partial Build, 62-500 Pkts/sec

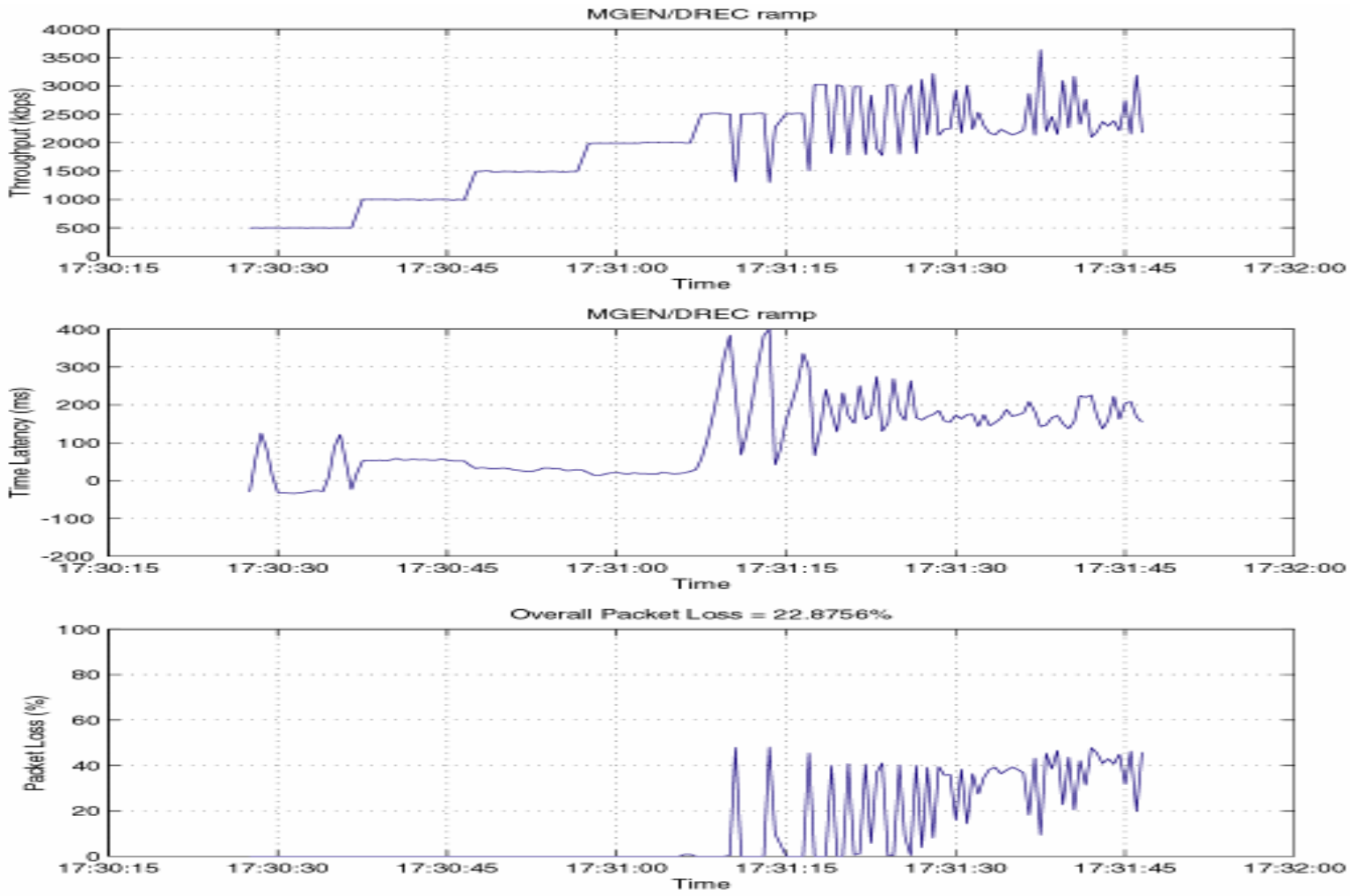


Figure 7

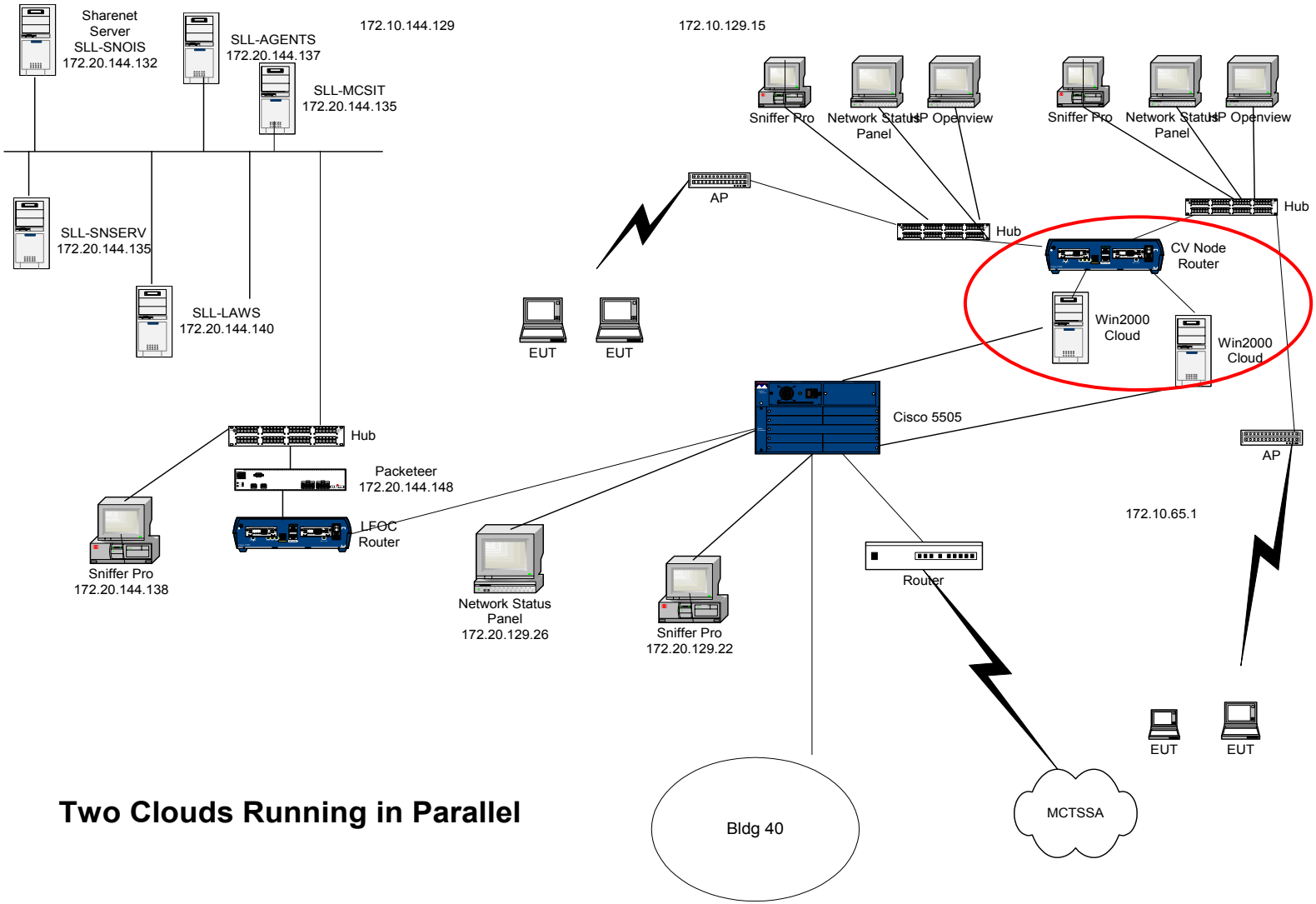
Numerous Results

- Numerous demonstrations / test support basic network performance numbers
- Army / DARPA Future Combat System Lead System Integrator Scalable Mobile Network
  - Winter 2003
  - New Jersey
- Ongoing testing by ONR (LC FNC) at MCTSSA
- Data in paper

Recommendations

- Build applications on networks “comparable” to tactical networks
- Use simulators ***all the time*** in application labs
- Remain aware of “trends” in tactical networking that could change the “guidance”
- Do not attempt to account for every minor nuisance in radio / network performance
  - ***Build to the general performance characteristics of a heterogeneous network***
  - ***NOT to the specifics of any one approach***
    - Radio / networks and applications should develop utilization abstraction
    - Expect radio / network protocol to change and evolve
    - Should not adversely impact applications
      - If it does it was a poorly designed application

ELB Application Test Network



Two Clouds Running in Parallel

Figure 8

ELB (and other)

- To large extent single biggest contributing factor to success of ELB was “forcing” application developers to develop / test using network simulators
- Application developers rarely had access to “real” network
  - Proved not to be a limiting factor
  - Was not needed – simulators proved to be wholly adequate and allowed applications and network to develop in parallel

ELB (and other) Settings

Cloud Settings

Cloud Parameter	Baseline	Worst Case	Goal
Bandwidth Limit – end-to-end (across Simulator, no limits on AP to EUT connection)	80 kbps	80 kbps	240 kbps
Latency – normal distribution (end-to-end)	Avg = 1000 msec Std Dev = +- 50 msec	Avg = 2000 msec Std Dev = +- 1000 msec	Avg = 1000 msec Std Dev = +- 50 msec
Link Fault – BER	10E-7	10E-7	10E-7
Link Fault – Network Disconnection	Avg. Freq of occurrence = 10 min Range of disconnect time = 20 sec - 1 min	Avg. Freq of occurrence = 10 min Range of disconnect time = 30 sec – 5 min	Avg. Freq of occurrence = 10 min Range of disconnect time = 5 sec – 20 sec
Packet Loss – Random Loss	20% loss	30% loss	10% loss

Figure 9

Summary

- Warfighter advances require the closer connection of C2 and comms for next big advance
- Don’t develop for or in “perfect” comms environment
  - Comms guys can not now nor ever be able to deliver it
- Develop using network performance specs, not particular radio / network types
- Data does exist to help develop a reasonable set of performance metrics to develop too