Challenges for Middleware Imposed by the Tactical Army Communications Environment

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presented 26 August 2003

IST-030/RTG-012 Workshop on 'Role of Middleware in Systems Functioning over Mobile Communication Networks'

Defence Research and
Development Canada

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Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **01 DEC 2007**	2. REPORT TYPE **N/A**	3. DATES COVERED

4. TITLE AND SUBTITLE **Challenges for Middleware Imposed by the Tactical Army Communications Environment**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Defence R&D Canada - Valcartier**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT **UU**	18. NUMBER OF PAGES **25**	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**			

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Revolution in Battlefield Command and Control

'Network-Centric Warfare'

– 'An information-superiority enabled concept of operations that generates increased combat power by networking sensors, decision makers and shooters to achieve:

- shared awareness

- increased speed of command

- higher tempo of operations

- greater lethality

- increased survivability

- a degree of self-synchronization

D.S. Alberts, J.J. Garstka, F.P. Stein, 'Network centric warfare: developing and leveraging information superiority', CCRP Publication Series, 1999

Revolution in Battlefield Command and Control

- Introduction of digital C3I systems

- Promise of increased battlefield awareness

- Need to distribute digital data

  – quickly

  – widely

  – reliably

- 'The right information to the right place at the right time'

Outline of Presentation

- Army command and control structure

- The tactical communications environment

- Challenges posed by the tactical communications environment

Army Command and Control Structure

Army Command and Control Structure

Information Flow

Plans & Orders

⬍

Microwave or Satellite link ▢

VHF/UHF Radio

⬍

Reports

Structure	Typical Organization Size
Army Corps HQ	30-50000 persons
Division HQ — **Division HQ** — Division HQ	10000+
Brigade HQ — **Brigade HQ** — Brigade HQ	3000+
Regimental HQ — **Regimental HQ** — Regimental HQ	1000
Battalion HQ — **Battalion HQ** — Battalion HQ	3-500
Company CP — **Company CP** — Company CP	100
Platoon CP — **Platoon CP** — Platoon CP	30

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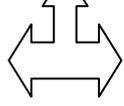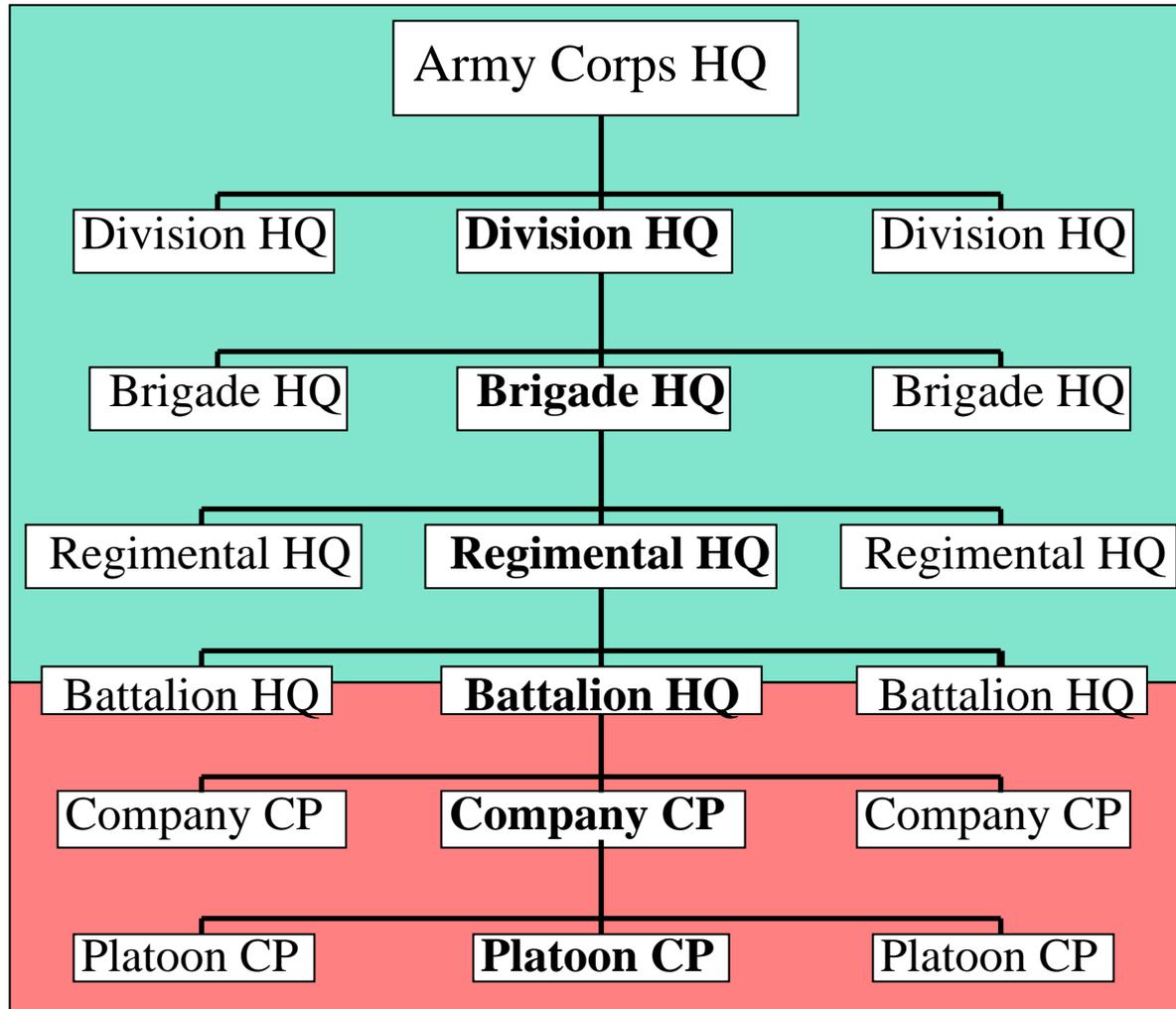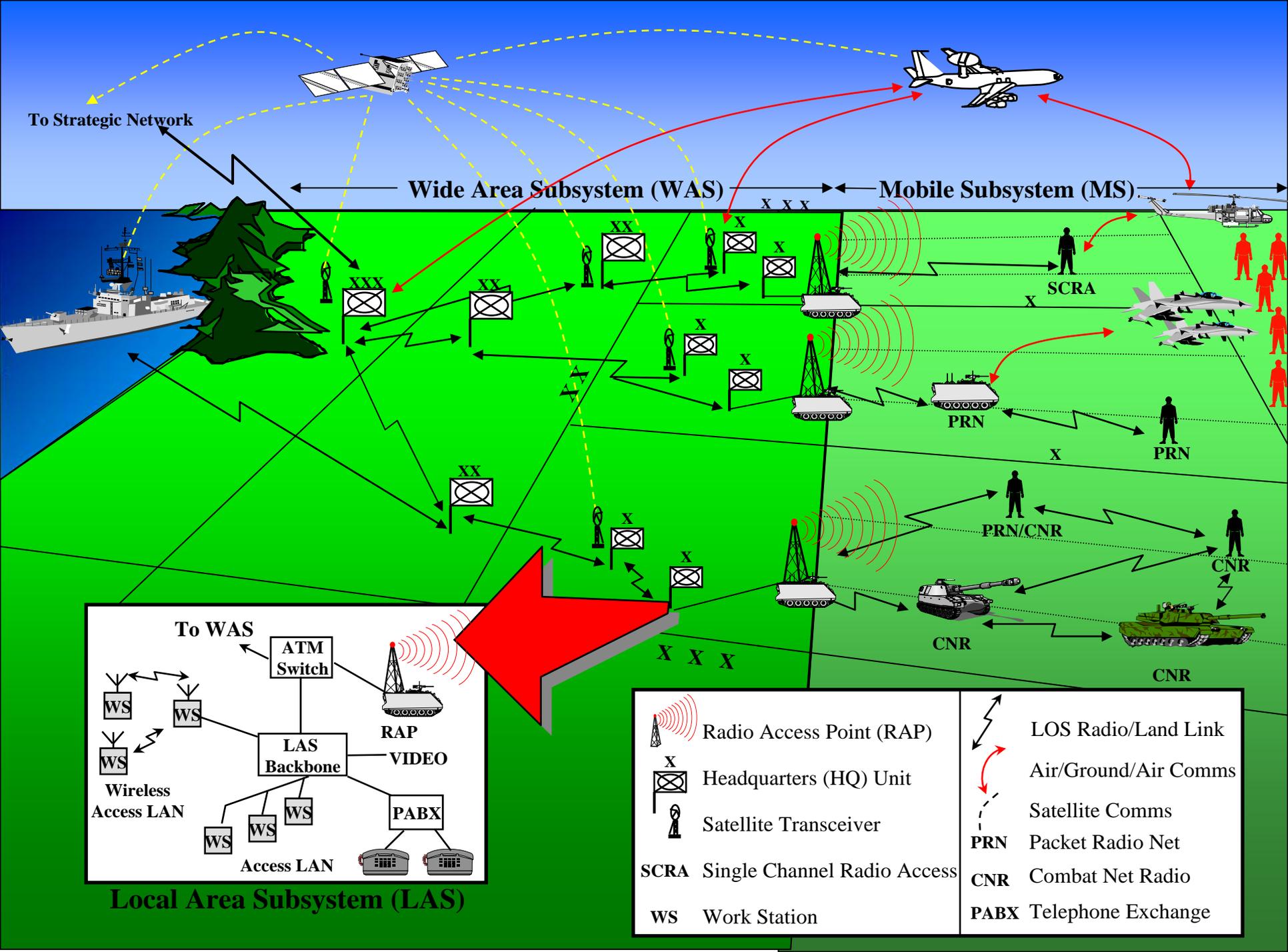
To Strategic Network

Wide Area Subsystem (WAS)

Mobile Subsystem (MS)

X X X

XX

X

X

X

X

SCRA

X

XX

X

X

X

X

PRN

PRN

XX

X

PRN/CNR

CNR

X

X

CNR

CNR

X X X

CNR

To WAS

ATM Switch

RAP

VIDEO

LAS Backbone

WS

WS

WS

Wireless Access LAN

WS

WS

WS

PABX

Access LAN

Local Area Subsystem (LAS)

Radio Access Point (RAP)

X — Headquarters (HQ) Unit

Satellite Transceiver

PRN Packet Radio Net

SCRA Single Channel Radio Access

CNR Combat Net Radio

WS Work Station

PABX Telephone Exchange

LOS Radio/Land Link

Air/Ground/Air Comms

Satellite Comms

The Tactical Communications Environment

Army C2 Structure -Tactical Domain

Information Flow

Plans & Orders

⇕

VHF/UHF Radio ▨

⇕

Reports

Brigade HQ

Regimental HQ	**Regimental HQ**	Regimental HQ

Battalion HQ	**Battalion HQ**	Battalion HQ

Company CP	**Company CP**	Company CP

Platoon CP	**Platoon CP**	Platoon CP

Section CP	Section CP	Section CP

Typical Organization Size

1000

3-500

100

30

8-10
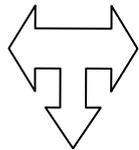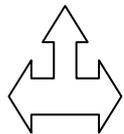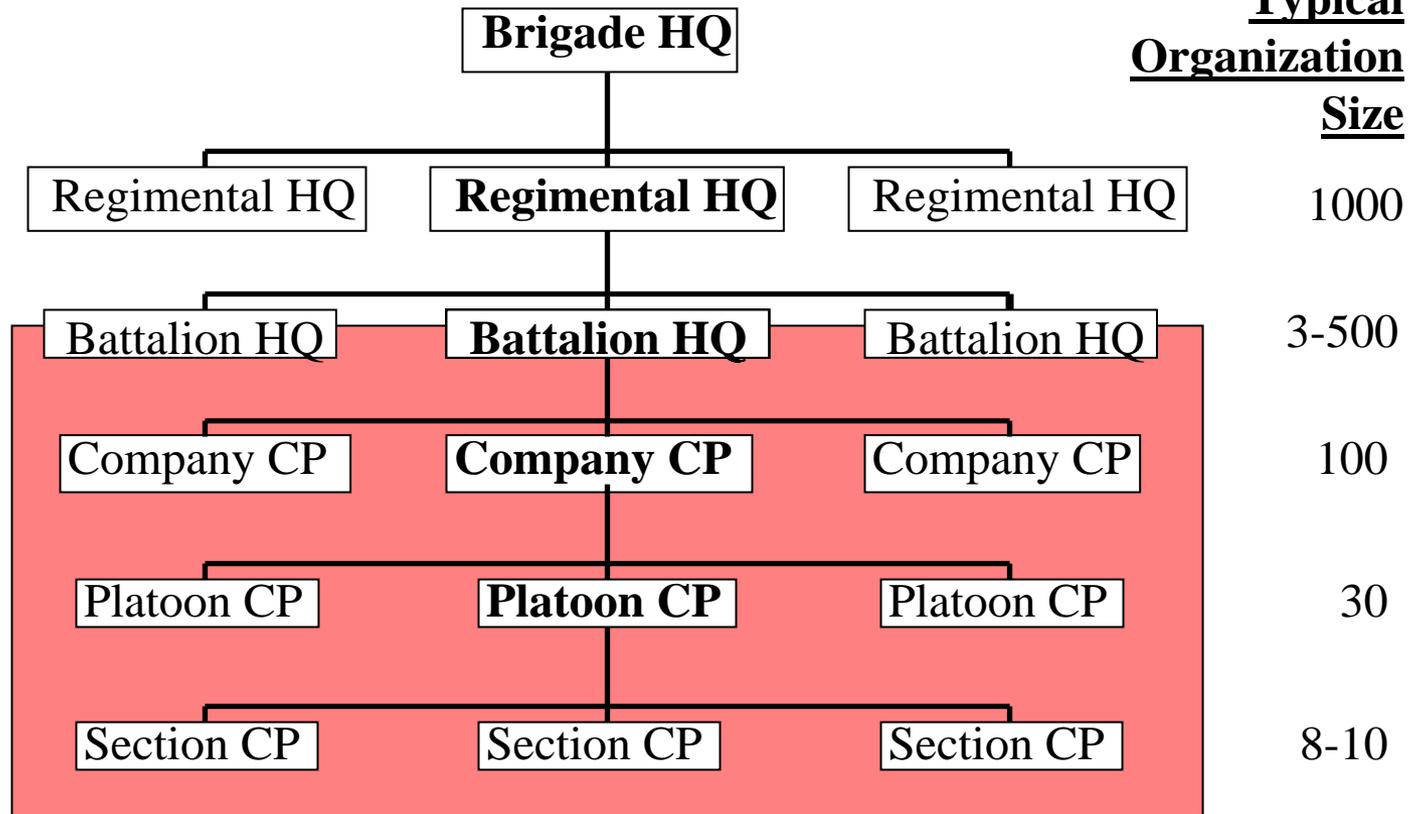
Notional Battle Group (augmented Battalion) Command Net

Company nets, each on a separate assigned frequency.

Comd

Altn CP

Tac CP

FSCC

Sigs Sqn

A Bty

BG CP

Recce TP

C Coy CP

Engr Sqn

B Coy CP

A Coy CP

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CNR Domain

•VHF: Vast majority of radios capable of 16kbps half duplex.

•UHF: Radios capable of 288kbps full duplex.
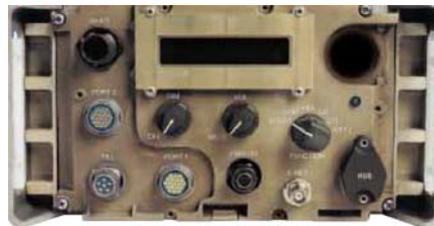
•High Band UHF: (e.g. 802.11) capable of 11 Mbps.

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Network Layers

Application
Presentation
Session
Transport
Network
Data Link
Physical

TCP/UDP
IP
Combat Net Radio VHF/UHF
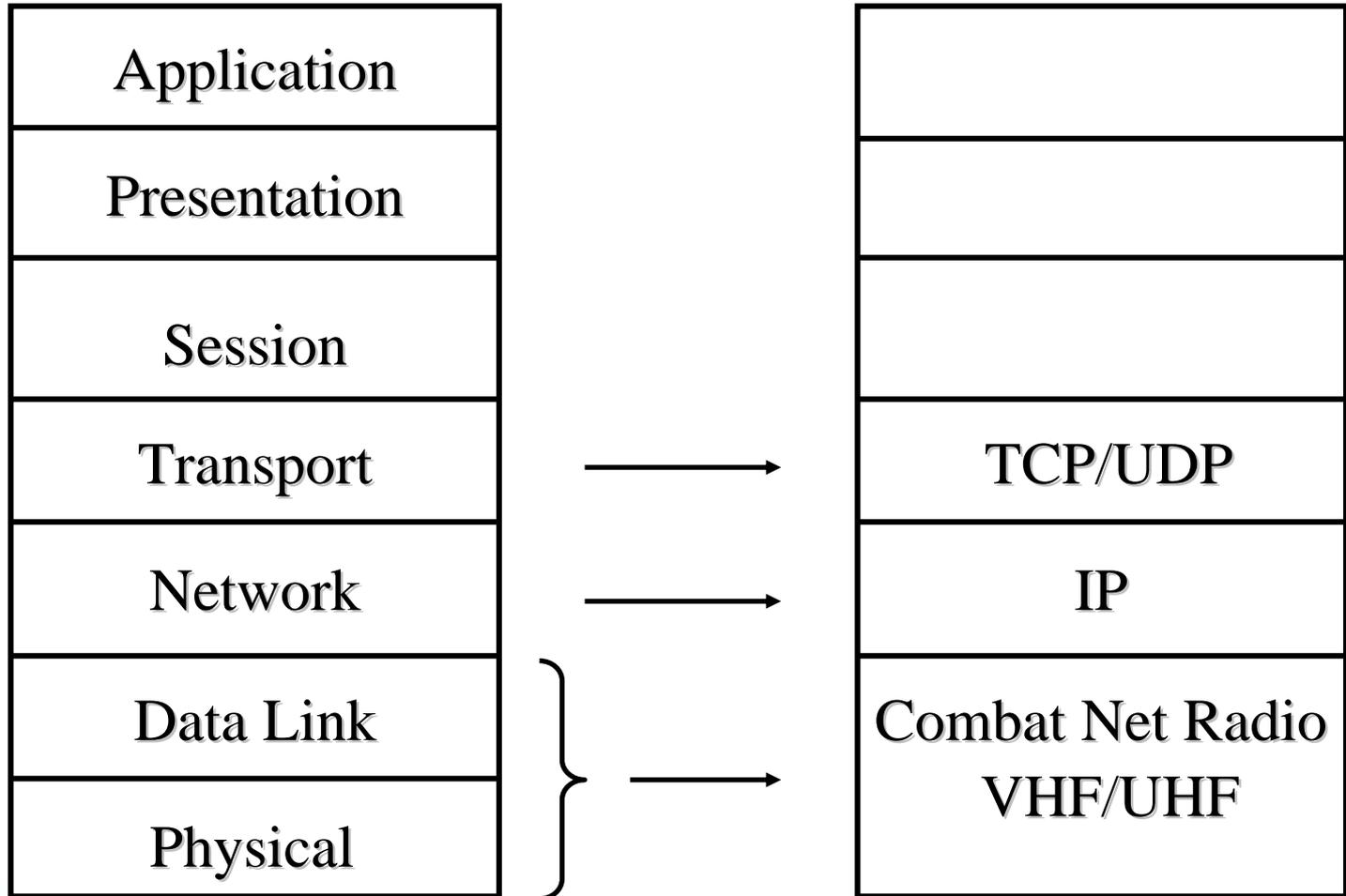
CNR – VHF (Canadian Example)

- Reality: usable throughput at the application layer is a fraction of the base rate:

  CNR(P) – Max throughput on DATA ONLY network: ~ 1kbps

  ## SHARED AMONGST USERS

  → 25 radios/net = 40 bps/user

- Reality: residual BER as low as 10^{-5}

- Other VHF CNR radios have similar performance

CNR UHF (225 – 450 MHz)

- Near Term Data Radio (NTDR)

  – 288 kbps is for 'well situated' sites

- Reality: true tactical environment performance is approximately:

  – ~16kbps from 22kbps link; and

  – ~80kbps using a 100 kbps link;

- Available throughput is still shared amongst users (80kbps/25 = 3.2 kbps)

- Error conditions similar to VHF

Transfer Control Protocol (TCP)

- TCP was designed for wired networks:

  - All controls designed for congestion, not errors

  - TCP is very sensitive to Bit Error Rate (BER) and Latency

  - Error in wireless domain trigger TCP congestion controls (e.g. 1 packet lost = 50% cut in tx rate)

  - TCP is connection-oriented → in wireless tactical domain (high BER, latency, long fades) TCP connections timeout regularly

TCP

- As a consequence…

Standard TCP is non-functional in most tactical wireless environments !!

TCP and Bit Error Rate

< 10% @ 10^{-7}

~0% @ 10^{-6}

Challenges Posed by the Tactical Communications Environment

Network Topology on the Tactical Battlefield

- Unreliable broadcast medium (radio) provides comms links

- Highly mobile entities participate as nodes on C2 network

- Network of sub-networks; each sub-net on different base frequency

- Nodes frequently connect/disconnect from subnetworks

- A single radio can participate on only one sub-net at a time.

  – participation on multiple nets requires multiple radios

- Number of radios in vehicle restricted by space limitations

Connectivity

- Planned loss of connectivity due to:
    - re-assignment of role for node
    - need to participate on multiple networks with single radio by switching frequencies
- Unplanned loss of connectivity due to:
    - terrain or atmospheric interference
    - nodal separation exceeding radio range
    - enemy jamming
    - damage due to enemy action
    - equipment malfunction

Tactical Communications Constraints

- Units are highly mobile

- Communicate by radio (voice and data; voice only; data only)

- Low data throughput (< 1 kbit/second for CNR(P))

- Variable data throughput

  – highly dependent upon traffic load on communications network

- Unreliable links (frequent disconnection, high bit error rates)

Data Distribution Requirements in Tactical Wireless Domain

- Autonomous cooperating nodes
  - disconnected operation
- Peer-to-peer model (not client-server)
  - avoid single point of failure
- Propagate updates asynchronously on 'all-informed' basis
  - profit from (shared) broadcast medium
  - change role without substantial one-time data transfer
  - recover data from any node
- Data recovery must be carefully managed (bandwidth issue)
- Data ownership an important issue (integrity and bandwidth)
  - single ownership of data to avoid/minimize data conflicts
- Negative acknowledgement scheme

The challenge – how to communicate and share information effectively in this highly constrained communication environment ?

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