FIFTEEN CONSTRAINTS ON THE CAPABILITY OF HIGH-CAPACITY MOBILE MILITARY NETWORKED SYSTEMS

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Abstract. The network centric warfare (NCW) model represents one of the defining trends in information age military technique. Its aim is to improve situational awareness and 'accelerate the observation-orientation-decision-action (OODA) loop'. While much literature exists which extols the virtues of NCW, the problem of what constraints exist on the capabilities of such systems has been explored much less frequently. This paper identifies no less than fifteen constraints on the capability of networked military systems, implemented with tactical datalinks, and explores their respective causes and implications.

INTRODUCTION

Network centric warfare (NCW) and the less ambitious model of network enabled operations (NEO), represent defining trends in the development of military systems and capabilities, for this decade. The aim of both is to reduce the time required to perform engagements, or 'accelerate the observation-orientation-decision-action (OODA) loop'. Less exact statements of aim include the notion of 'dispelling the fog of war' by using the network to rapidly gather and distribute information [1,3,5,17].

A key consideration for planners and architects of such systems is that of what constraints exist on the achievable capabilities of such a system, which is typically implemented using highly mobile tactical datalink technology. Such constraints do exist and the aim of this study is to identify these constraints and establish how they constrain the capability or utility of the network.

In the broadest sense, these constraints can be divided into two categories:

- Hard limits imposed by the physics of radio signal propagation and the mathematical properties of networked systems.
- Impairments resulting from hostile actions, and human constraints on the system.

The potential for any specific network to be implemented and used successfully will be determined by these constraints, which become increasingly relevant as the intended network approaches the hard limits imposed by physics and the mathematical properties of networks.

No less than fifteen specific constraints or limits have been identified. We will analyse each in turn, and where applicable, the implications of not considering their impact. This is especially important in terms of identifying differences in constraints which apply to cabled non-military networks. It is implicitly assumed that such networks are implemented using wireless radiofrequency digital datalinks.

THE POWER-APERTURE CONSTRAINT

The channel capacity of any wireless radio link is limited by the radio frequency power output of the transmitter, the bandwidth available within the radio spectrum, and the size of the antennas used, for any given distance between stations, in free space. This is the Friis power-aperture or path length loss equation, which constrains all radio-frequency communications [22].

Most established mobile military networking equipment, such as JTIDS/MIDS/Link-16 terminals, employs omni-directional low-gain antennas, and transmitters with power ratings of the order of ten of watts to kilowatts. For instance, a time division multiplexed JTIDS/MIDS/Link-16 network provides capacities between tens of kilobits/sec to Megabits/sec, subject to configuration. Characteristically, most such systems are implemented with omni-directional antennas to facilitate high mobility, without the cost impediments of a steerable antenna main lobe. Subject to constraints in bandwidth and modulation, achievable capacity is thus bounded by Friis [20].

In the broadest theoretical sense, unlimited bandwidth and power, and antenna aperture size permit unlimited growth in capacity. Pragmatic constraints will inevitably set hard limits on capacity. A good comparison is that of establishing what kind of radio-frequency link would be capable of competing in channel capacity with an optical-fibre link of Gigabit/sec class capacity. An extensive study by Kopp [12,15], in part since empirically validated by US industry [11], exploring high speed airborne ad hoc networks established that to achieve Gigabit/sec class capacity in an X-band or Ku-band radio-frequency network, over distances of tens to hundreds of kilometres, requires the use of power levels, antenna aperture sizes and receiver performance comparable to that of a contemporary active electronically steered antenna (AESA) radar on a fighter aircraft.

To provide an aircraft, warship or vehicle with 360° very high speed network link coverage with such performance thus requires three to four such antenna/transceiver systems. The cost of such an installation would be dominated by the AESAs employed, which at current radar costs would result in an installation cost of millions of dollars per platform. For many military platforms such installations are not feasible for reasons of size and weight, regardless of cost.

This problem is often described in terms of the 'range/capacity/mobility' trade-off, where the need for mobility and reasonable transceiver/antenna costs conflicts with the demand for power-aperture performance to affect high channel capacities [27].

The often-asserted expectation that Moore's Law driven miniaturisation seen in computer hardware will apply to high-speed radio-frequency computer network hardware is false, as it fails to account for the physics of antenna aperture design, constrained by the Friis power-aperture equation. *Put*

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