# A Revised Calculation on the Value of Networking as Applied to Airborne Platforms

John Dahlgren
Curtis Evans
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# Outline

- General Networking Concepts
- Formulas for Determining Network Value
- New Paradigm on Network Value for Military Operations
- Summary


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# What is a network?

**From Merriam-Webster Dictionary**

**Main Entry:** net·work
**Function:** ***noun***

3 a : **an interconnected or interrelated chain, group, or system <a *network* of hotels>** b : **a system of computers, terminals, and databases connected by communications lines**
4 a : **a group of radio or television stations linked by wire or radio relay** b : **a radio or television company that produces programs for broadcast over such a network**


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# Purpose of a network

- Transfer data and information (processed data) between nodes
- Nodes are where the data and information are created, processed, deleted and/or forwarded
- The network is an enabler; it provides the nodes with access to other nodes
- Nodes are part of the network – without nodes there is no network


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# Node Composition

- Modern nodes often consist of an electronic device to create, process, delete, forward and/or store information
- Attached to most nodes is a person; although machine-to-machine transfers of data are possible and do not require human intervention for some applications
- The person is still the most important part of the communication string since the person is still the ultimate information user


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# Why do people belong to networks?

## Military

- Communicate
  - Email
  - Instant Message
  - Voice
- Maintain situational awareness
  - News
  - Weather
  - Schedule (ATO)
  - COP (Blue and Red)
  - Intel
- Make Decisions
- Take Action
  - Targeting (Find, Fix, Track)
  - Engage
  - Assess
  - Logistics Transactions

## Personal

- Communicate
  - Email
  - Instant Message
  - Voice
- Maintain situational awareness
  - News
  - Weather
  - Finances
  - Schedule
- Make Decisions
- Take Action
  - Shopping
  - Buy/sell stocks
  - Pay bills


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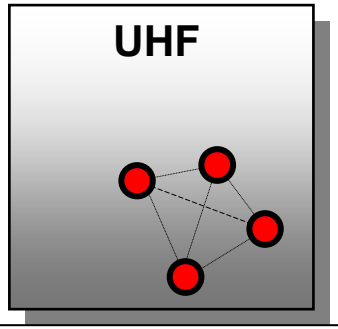
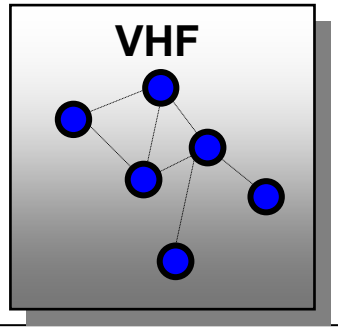
# Military Networks

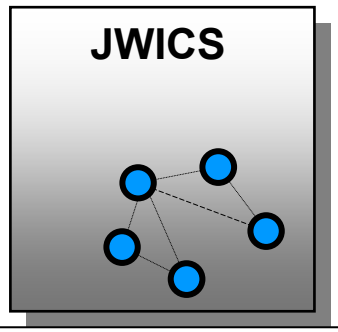
**Voice**

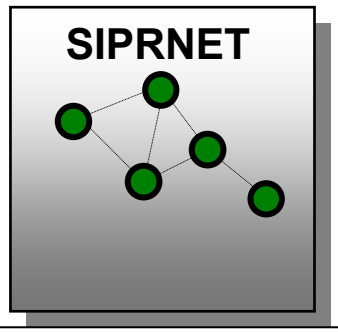


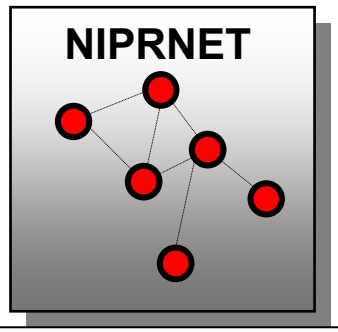




In order for various military COIs to accomplish their missions they have formed specific networks to access the needed data and information

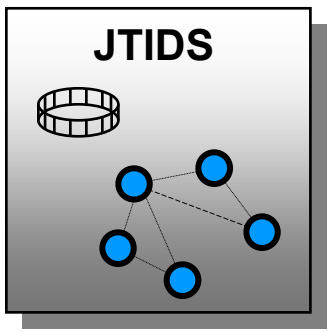
**IP Networks**

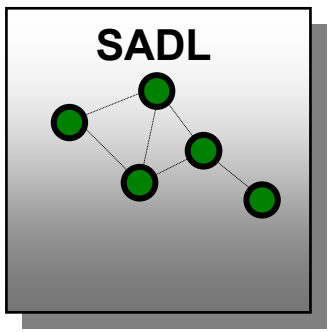


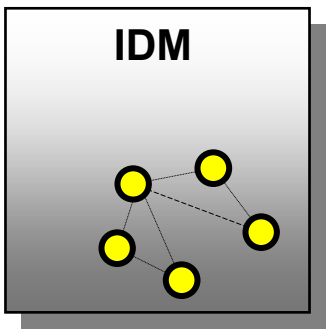



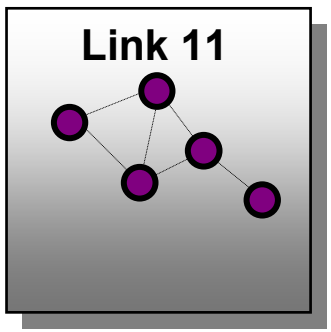



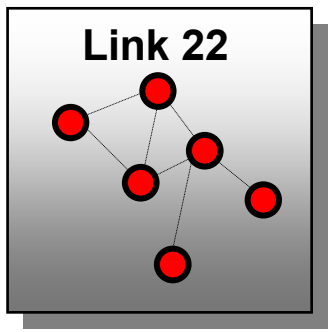

**Tactical Data Networks**





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# Size of the Network

- It is generally accepted that the greater the number of people and/or nodes in a network the more valuable the network
  - Access to more people/Communities of Interest (COI)
  - Access to more data/information
- However with more nodes come questions
  - Can I find the data I need?
  - Is it timely enough to be relevant?
  - Is it trustworthy and accurate?
  - Can I reach data overload?


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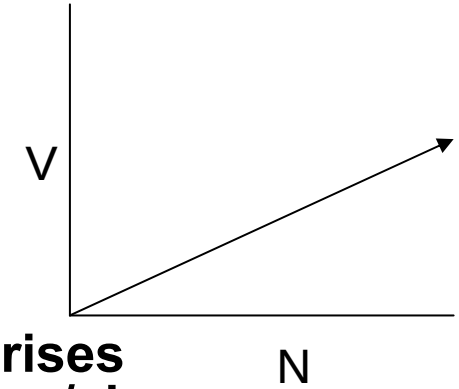
# How do you measure the value of a network?




## Sarnoff's Law (Broadcast)

- Sarnoff's Law states that for one-way broadcast communication, the value of the network (V) itself rises proportionally to N, the potential number of listeners/viewers.
- V(network) $\alpha$ number of users; $V \alpha N$
- Political campaigns understand the power of this law, through their heavy use of mass media outlets for pre-poll party and candidate advertising
- Television networks charge increasing advertising rates proportionate to the number of viewers for each television show, or 30 minute segment
- A current day amendment to Sarnoff's Law might be:
  - $V_{network} = \sum_{i=1}^{17520} V(\text{30 minute time slots})$
  - There are 17520 – 30 minute time slots in a year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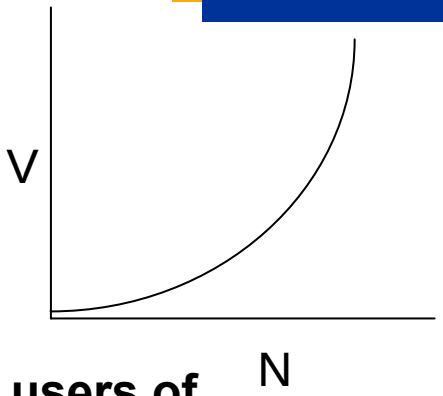


**Metcalfe's Law (Transactional)**

- **Metcalfe's law states that the usefulness, or utility, of a network equals approximately the square of the number of users of the system ($N^2$). Since a user cannot connect to itself, the actual calculation is**
  - ***N*(N − 1), or $N^2 - N$.**
  - **Often simplified to V(network) = $N^2$**
- **First formulated by Robert Metcalfe in regard to Ethernet, Metcalfe's law attempts to explain many of the network effects of communication technologies and networks such as the Internet.**
  - **Metcalf's law failed during the .com bubble since each company didn't increase in value according to the number of people in the network**
  - **Metcalf's law incorrectly implies that providing the Manhattan White Pages to people in Virginia has the same value as providing the local white pages**
- **The law is often illustrated with the example of fax machines: A single fax machine is useless, but the value of every fax machine increases with the total number of fax machines in the network, because the total number of people with whom you may send and receive documents increases.**


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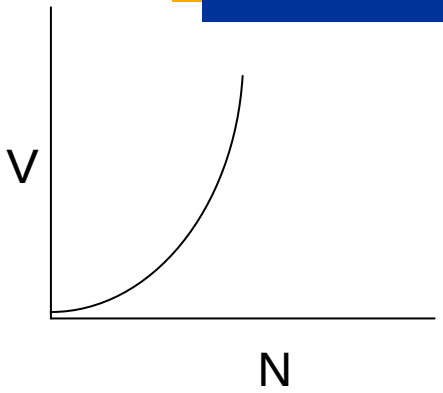


## Reed's Law (Group Forming Networks)

- Reed's law is the assertion by David P. Reed that the utility of large networks, particularly social networks, can scale exponentially with the size of the network.
- Often simplified to V(network) = $2^N$
- Reed actually believed the Value of a network is a combination of Sarnoff, Metcalf and Reed's assertion
  - V(network) = $aN + bN^2 + c2^N$
  - a>>b>>c
- At the beginning the value scales as N, as the network grows the value scales as $N^2$ even though b<<a, and then network value scales as $2^N$ even though c<<b
- Reed believes that while participants don't use every possible connection, an network provides an option on the use of a large number of connections.


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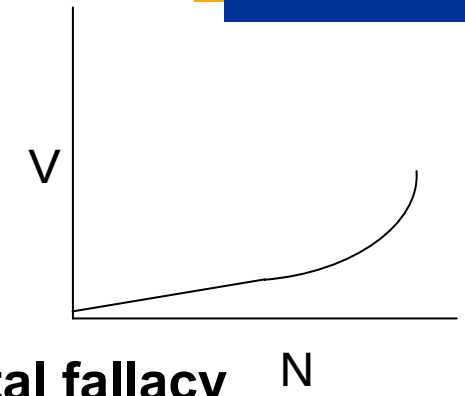
# How do you measure the value of a network?




- Odlyzko and Tilley assert that there is a fundamental fallacy underlying Metcalfe's and Reed's laws which the equations imply that all groups are equally valuable.
- The rule of thumb becomes: "the value of a network with N members is not N squared, but rather N times the logarithm of N." Their primary justification for this is the idea that not all potential connections in a network are equally valuable. For example, most people call their families a great deal more often than they call strangers in other countries, and so do not derive the full value N from the phone service.
- V = Nlog(N)
- A key point here is that Odlyzko and Tilley believe that all groups (connections or COIs) are not of equal value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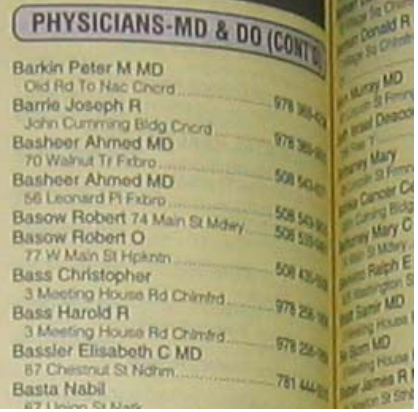
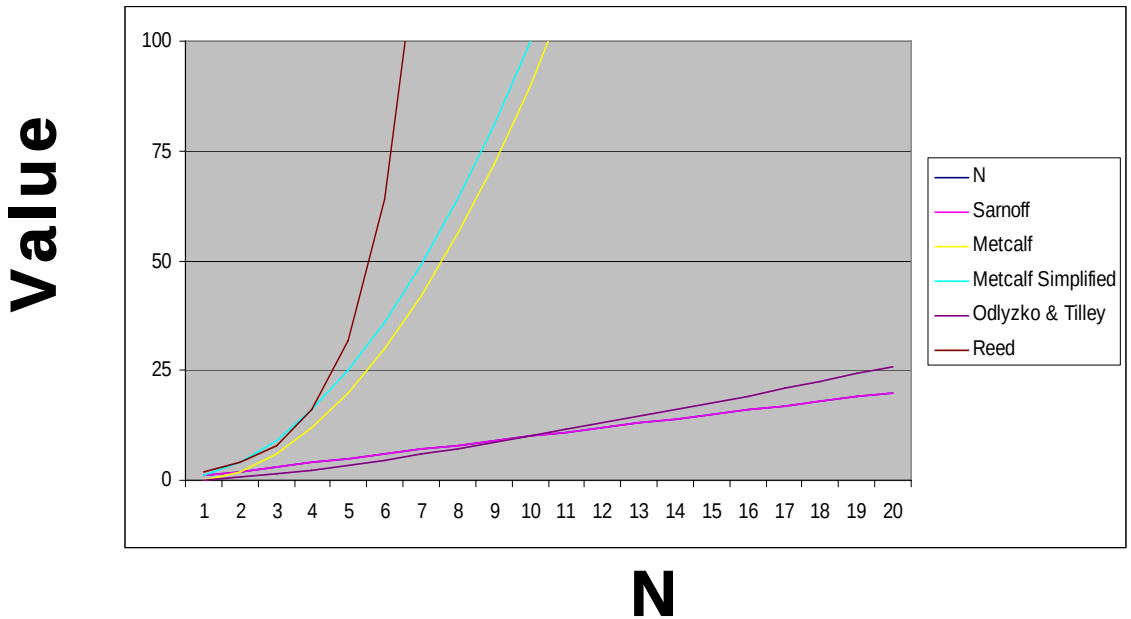



# Value of Network




**Sarnoff, Metcalfe and Reed believe that more nodes in the network add value, but is this accurate for military operations?**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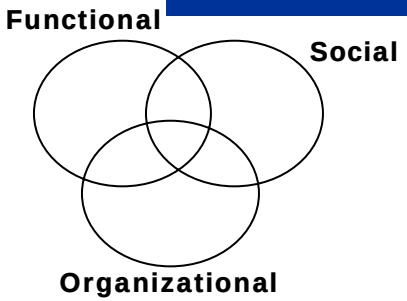
# Communities of Interest




- Web communities form between groups who share common interests
- People/nodes can belong to more than one Community of Interest (COI). COIs could be
  - Organizational
  - Functional
  - Social/Personal
- Organizational and Functional COIs often overlap, and lead to development of Social/Personal COIs
- People tend to share more information with people in their COI(s) (Power law & military example)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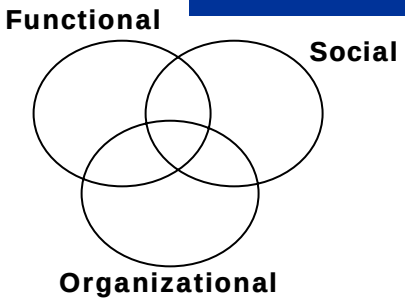
# Communities of Interest (continued)




- In performing a military operation, COIs are very important
- In order to perform a mission, specific sources of information are needed and thus specific COIs have formed and also in some cases distinct networks have been built to support those COIs
- Because of most mission's time-sensitive nature, the links to other nodes must be pre-determined; very little ad-hoc searching the network for information is necessary or even possible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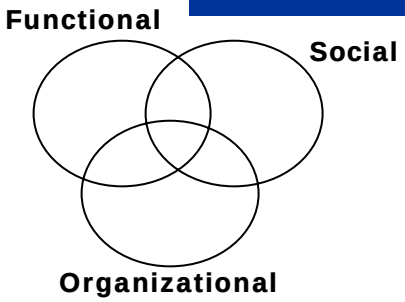
# Some Common COIs




## Personal

- Jobs
- Family
- Where You Live
  - Local Roads
  - Zoning Issues
- Hobbies
- Education
  - Kids' schools
  - Parents Continuing Ed
  - PTA
  - Alumni Association
- Finances
  - Banking
  - Investing
  - Mortgage
- Shopping
- Charitable Groups
- Religious Affiliations

## Military

- Command & Control
  - AOC
  - ASOC
  - TACP
- Intelligence
- Space Ops
- Acquisition Community
- Time Critical Targeting
- Close Air Support
- Combat Search & Rescue
- Special Operations
- Logistics
- Base of location
- UCC, Service, Agency
- Family Support Center
- BX & Commissary
- Officer/NCO/Airmen/Top-3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# Impedances to Network Value -- Distance

- Zipf's Law: V proportionate to $AB/d^{\acute{\alpha}}$; $1<\acute{\alpha}<2$
  - d = distance between A and B
  - A, B = respective populations of two cities
  - Zipf believed increasing the distance between two nodes decreases the value of the connection
  - Zipf's law may be situational dependent
- While originally internet traffic was predicted to be 80% local (or within the building) and 20% outside of the local area, the tide has turned to Internet traffic becoming much less dependent on locality
- d likely relates to mouse clicks or cultural issues, and no longer relates to geographic distance
  - For instance, many local e-mails have little value whereas most e-mails from a distant connection have significant value
- A modern update to Zipf's Law should substitute impedance to making a connection for distance (d)


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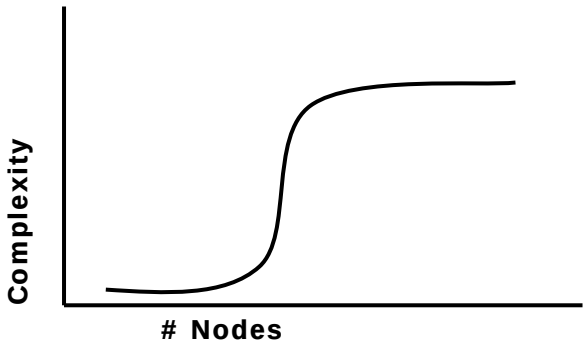
# Impedances to Network Value -- Information Overload

- Individuals, nodes, and networks have a limited complexity level with which they can operate
- Increasing the number of active nodes that must be dealt with or responded to moves a node towards information overload.
- "plecticity" characterizes the combined positive and negative effects of network complexity and collaboration" Moffatt p 136
- Complexity Curve:




Moffatt p 135

- Information overload ranges from 1 (almost no nodes and little complexity) to infinite (large number of nodes and tremendous complexity)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# Impedances to Network Value -- Combining Dissimilar Networks

- Sarnoff, Metcalfe and Reed seem to assume that nodes can easily join the network (same protocol)
- The military situation is that we have IP terrestrial networks but also separate, unique airborne tactical data networks
- An added dimension to the problem is the cost of merging the networks; making vital information available to the enterprise and eliminating the stovepipes
- The challenge is to minimize the cost for nodes to join the network, to more efficiently participate in COIs, and thus add value to the node and the COIs


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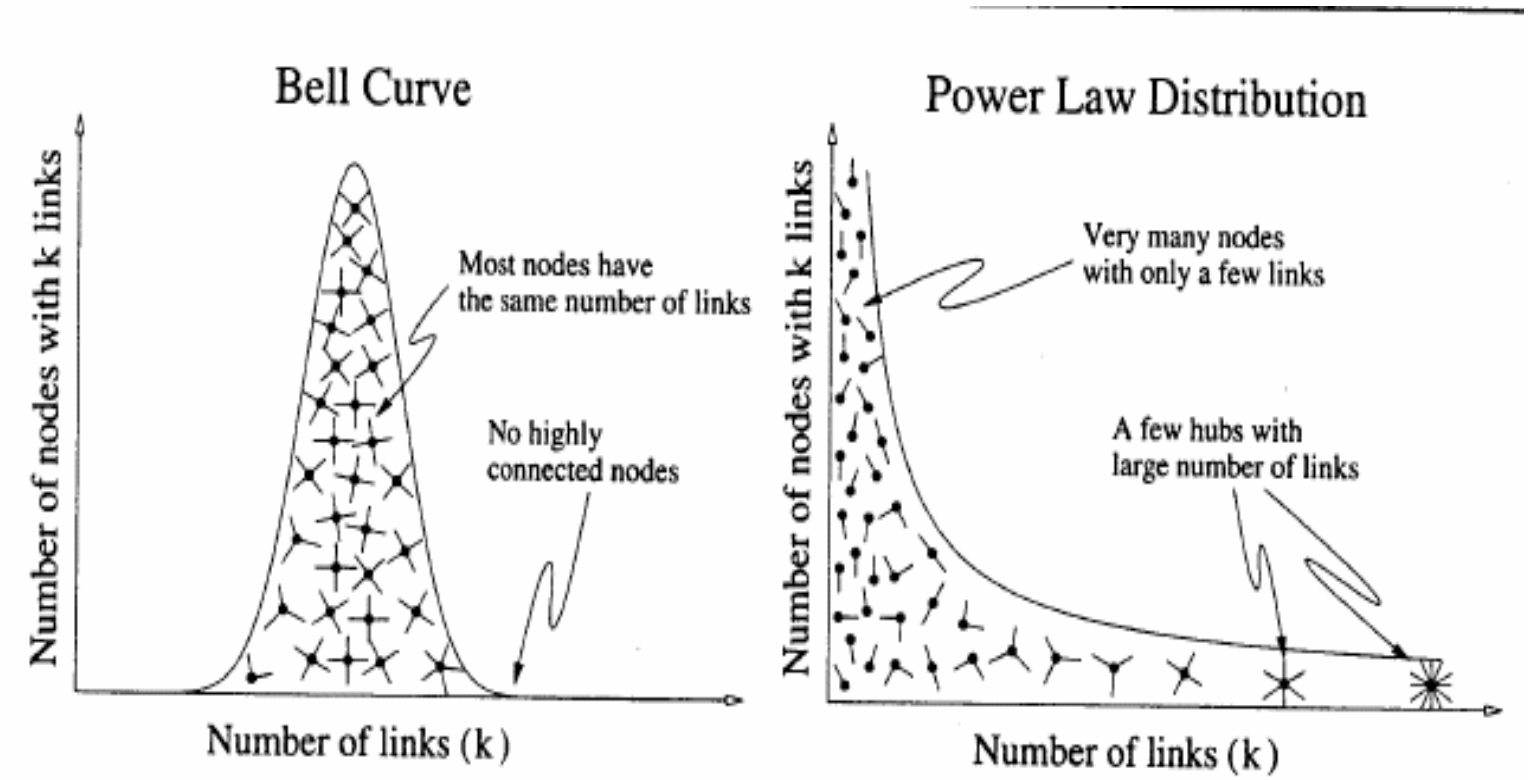
# Power Laws Predict Hubs/Connectors (80/20 rule)





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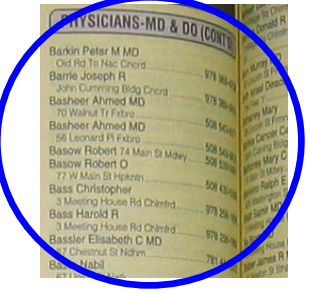
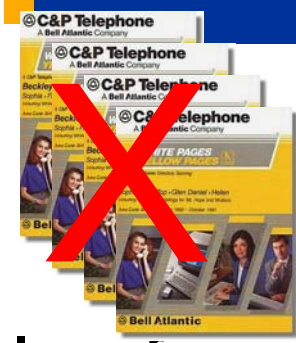


# Value of Networking – A New Paradigm




- **Dahlgren & Evans Law: People actually derive the full value of any network as life needs/missions change. People often need much of what is offered by the network, just not all at once or maybe not even over many decades.**
  - **For example, people may not need a pediatrician for 25 years (if ever), then they may need one for about 10 years, and they may not ever need access to one again**
- **The bottom line is not whether the value increases exponentially or logarithmically with the number of users but that…**
- ***The value or usefulness of a network***
  - ***increases with the value of each of the COIs of my interest (V $\alpha$ V(COIs))***
  - ***decreases with the time required to join an additional needed COI (V -$\alpha$ time (t) required to join a COI)***
  - ***decreases with the cost of joining an additional needed COI (V -$\alpha$ cost (C) of joining a COI)***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# Value of Networking – A New Perspective

- **Therefore,**
  - **V ≠ size of any particular COI or the size of the total network**
  - **V = f(V(COIs), t(joining a COI), C(joining a COI), C(impedance), C(complexity)**
  - $V = \sum_{i=1}^{N} V(COI)_i$, **1<i<20**



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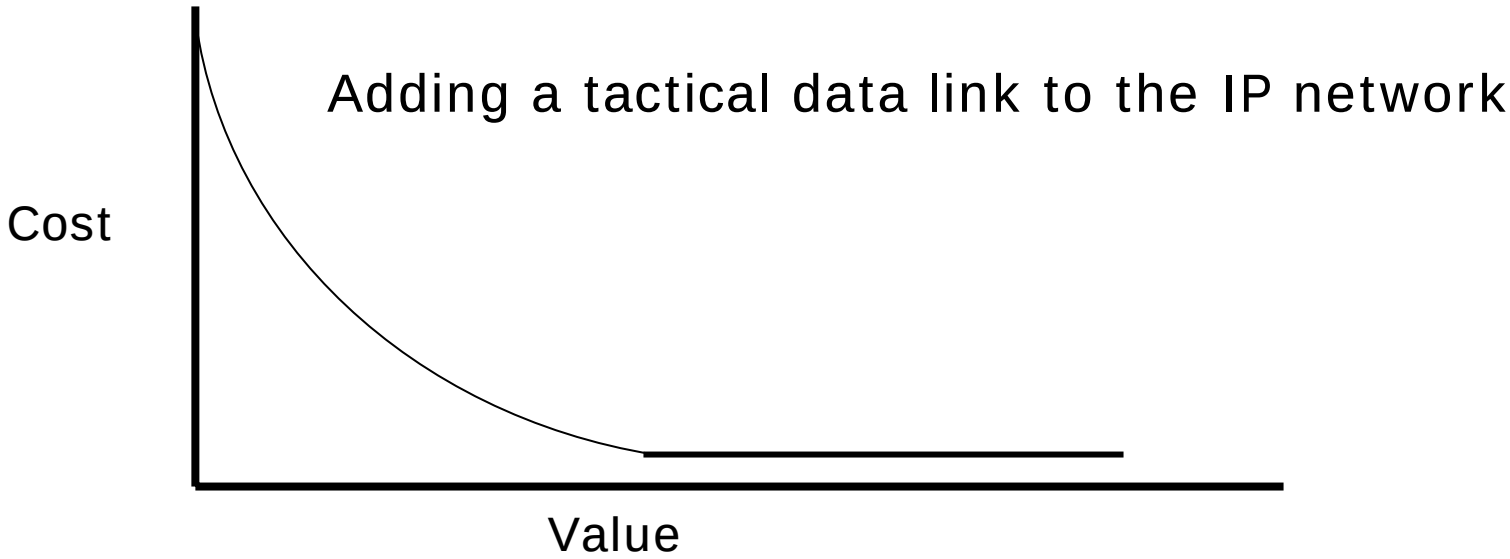
# Value vs. Cost of Joining COIs




Initially a large fixed cost to join (for aircraft) then the cost of joining each successive COI is negligible compared to the value gained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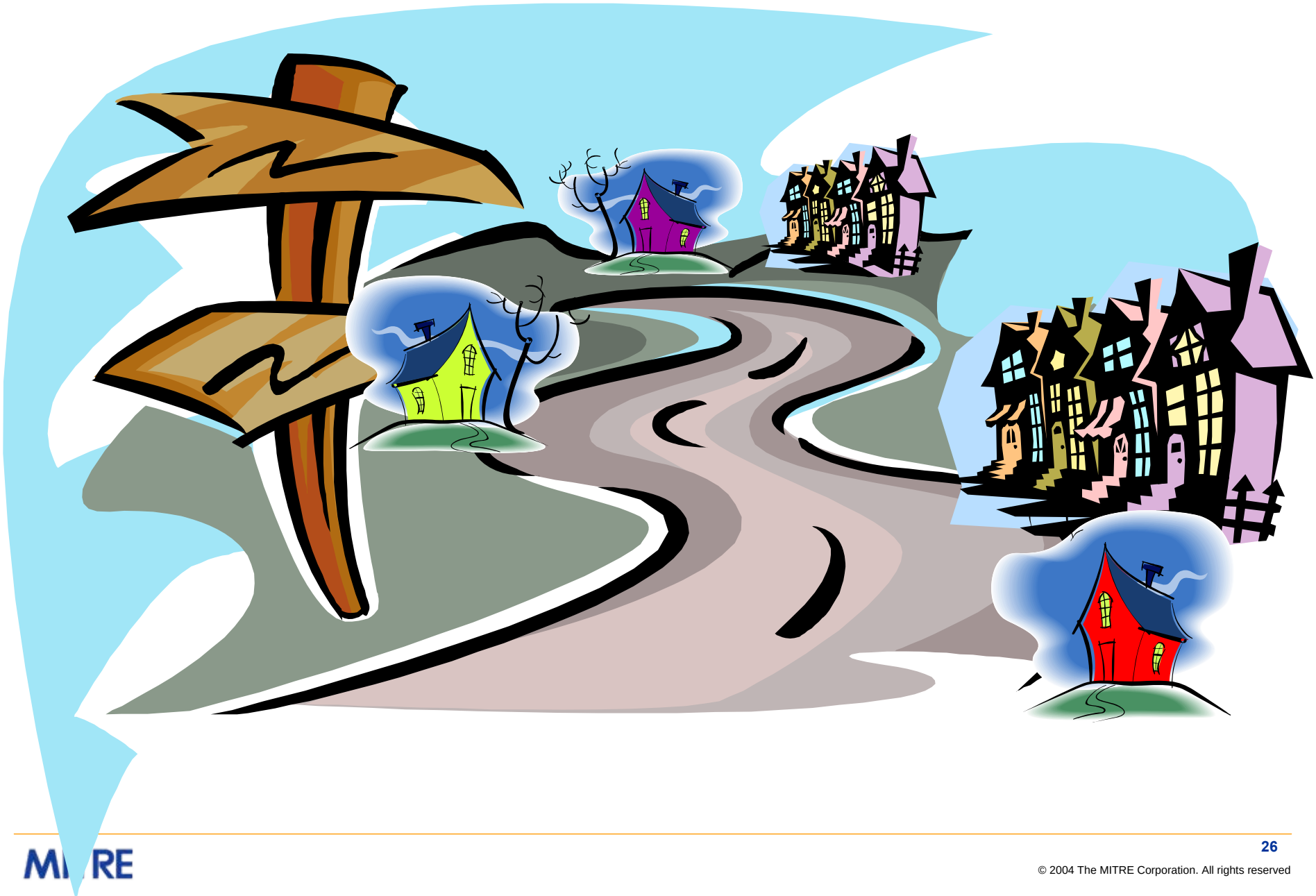
# How to Value a Road, or any Infrastructure?





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# Summary

- Networks are enablers; they connect nodes together
- Nodes are where data and information are processed
- Networks can take on many shapes and sizes: people, electrical, computer, communication, etc.
- As nodes are added to a network, value is also added up to the point where additional nodes add more complexity than value
- Nodes tend to connect more often and share information with other nodes of like interests, forming COIs
- A positive attribute of a valuable network is that it allows nodes to connect quickly and to share information easily
- If you have two separate networks using different protocols, then there is a cost associated with combining the two networks
- In order to make the separate tactical data links and IP networks more valuable to the military, we must make it possible for nodes to easily connect and share their information


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# Conclusions

- The value of an IP network cannot currently be determined to an exact measure
  - Metcalfe and Reed overestimated
  - Sarnoff's law works well for TV & radio
- The authors have come to believe that the value of a network is
  - V = f(V(COIs), t(joining a COI), C(joining a COI), C(impedance), C(complexity))
  - $V = \sum V(COI)_i, 1<i<20$
  - Joining too many COIs will cause a complexity penalty
- The network will enable military COIs to form according to functionality and then organization, enhancing the effectiveness of the organization and diminishing the impact of geographic separation
- Implementing the AN will have a high initial cost that will quickly become minimal in comparison to the value provided by the IP network


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