

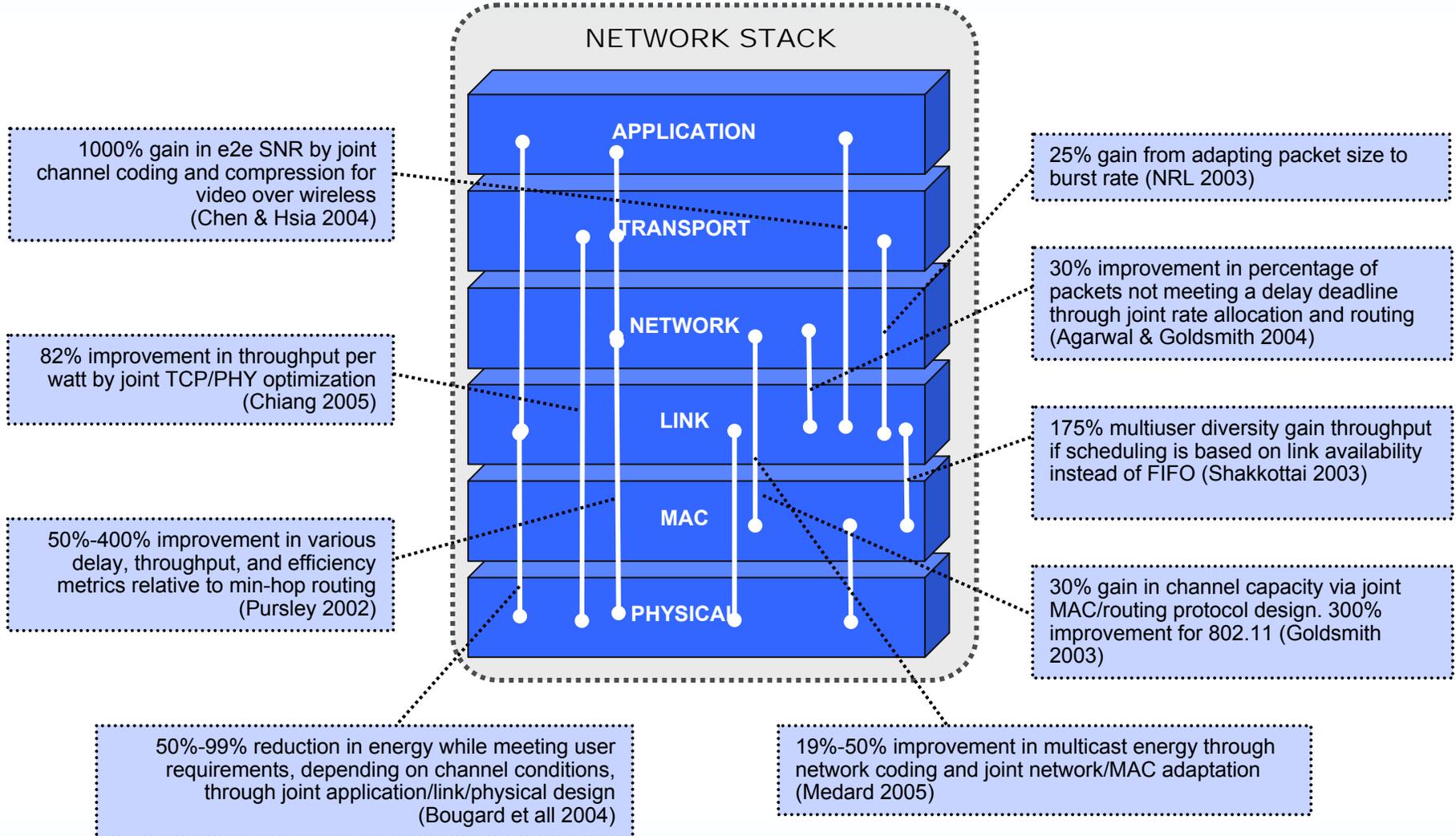


# CBMANET, ITMANET Overviews for WAND Proposer Day meeting

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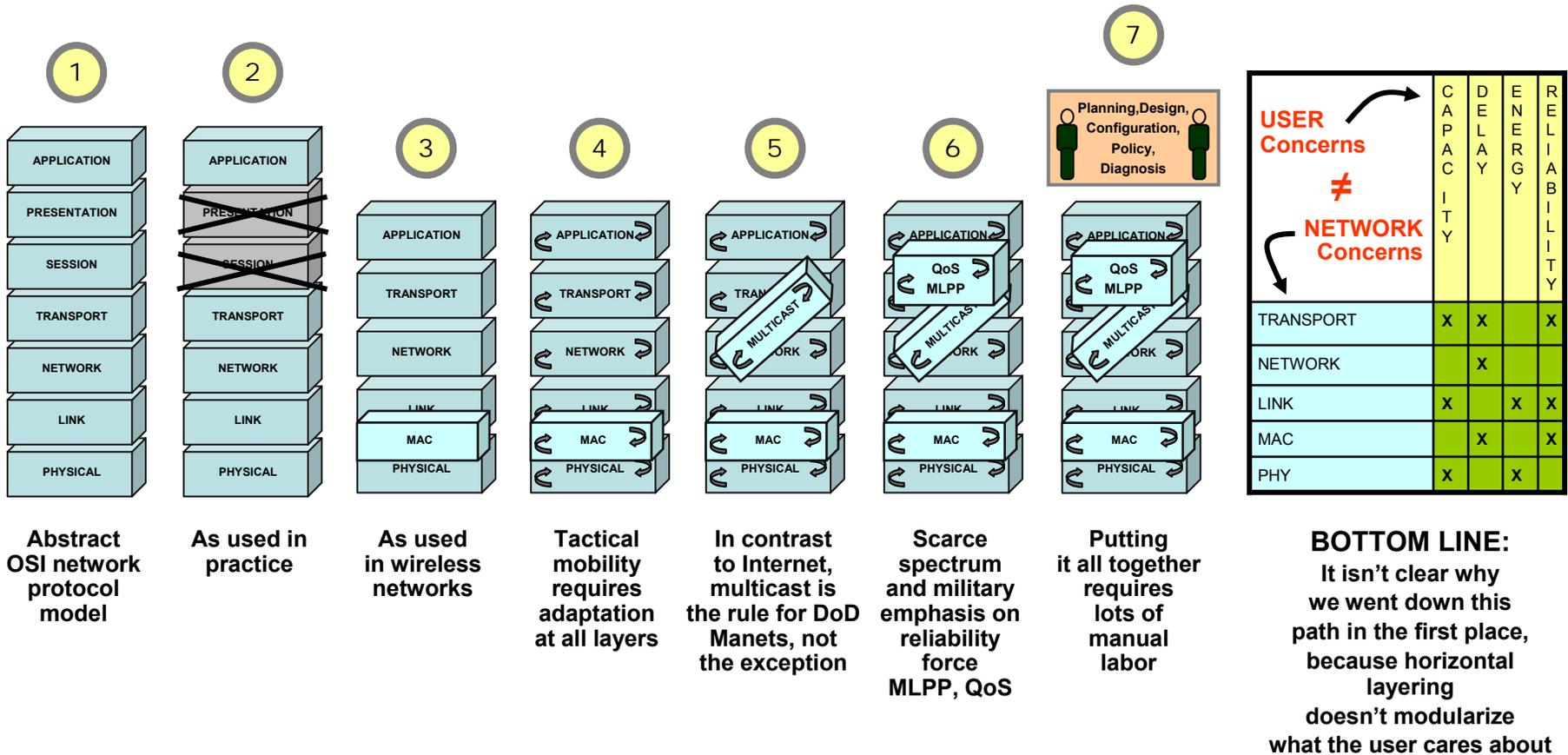
# An intriguing mystery raised by x-layer research



**What is the “right” wireless network stack, if this is not it?**

# Root cause of layering suboptimality

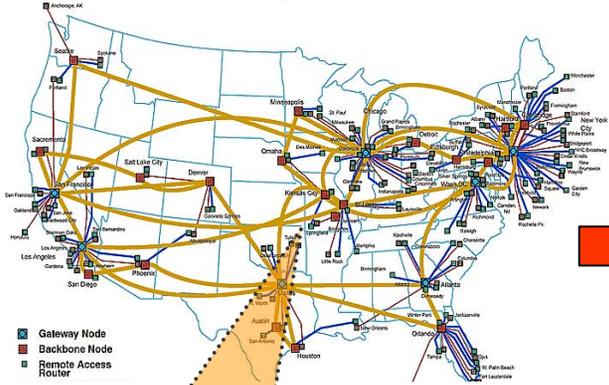
*How did we get into this situation – and what do we need to do:*



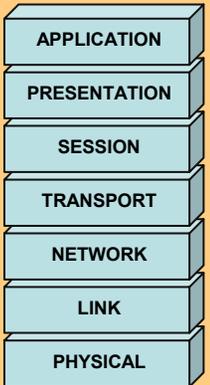
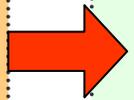
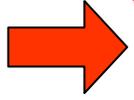
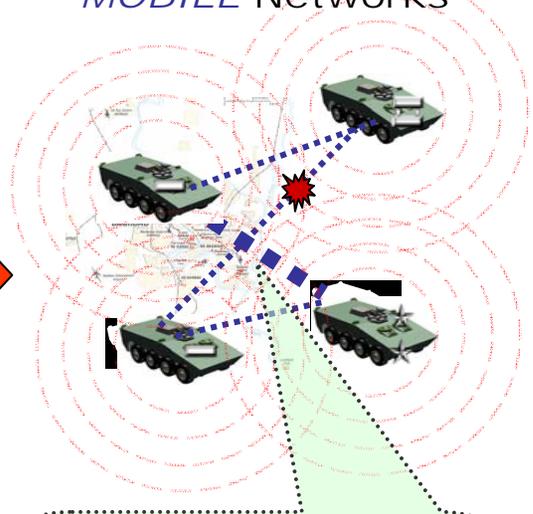
**Traditional “design by committee” stacks are modularized to optimize evolution, not user concerns**

# DARPA CBMANET: Clean-slate wireless networks

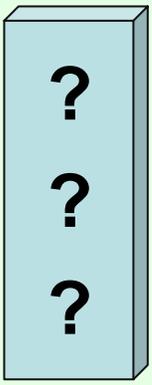
## Traditional WIRED Networks



## DOD WIRELESS MOBILE Networks



**PROBLEM:**  
Traditional "network stacks" are optimized for WIRED networks



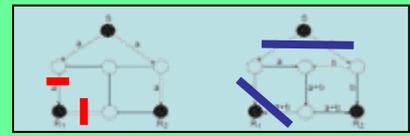
**SOLUTION:**  
Jettison the baggage of Internet protocols and develop a revolutionary approach to wireless networking

## CBMANET Benefits for the User:

- Perception of 10x more data rate, less overhead and repetition
- Less fragile communications in dynamic mobile settings
- Dramatic improvements in DOD applications such as multicast voice
- Manual network tuning replaced with automated adaptation

## Key New Ideas:

### • Network Coding

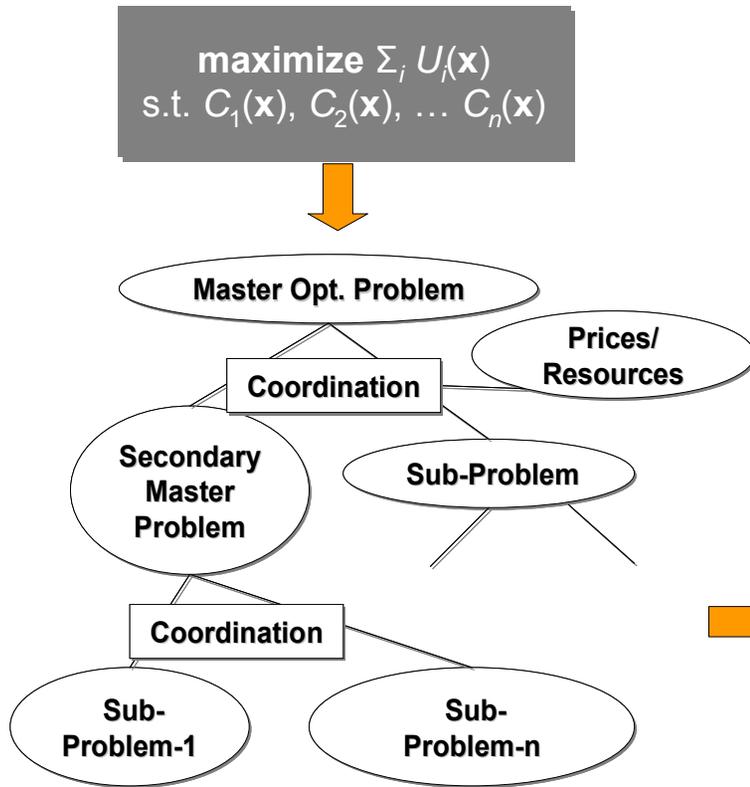


### • Optimization Decomposition

$$\begin{aligned}
 &\text{maximize} && \sum_s U_s(x_s) - \sum_j V_j(w_j) \\
 &\text{subject to} && \mathbf{R}\mathbf{x} \preceq \mathbf{c}(\mathbf{w}, \mathbf{P}_e), \\
 & && \mathbf{x} \in \mathcal{C}_1(\mathbf{P}_e) \cap \mathcal{C}_2(\mathbf{F}), \\
 & && \mathbf{R} \in \mathcal{R}, \mathbf{F} \in \mathcal{F}, \mathbf{w} \in \mathcal{W}.
 \end{aligned}$$

**CBMANET is exploring two potentially complementary paradigm shifts in stack design**

# Candidate paradigm shift: From design-by-committee to *design-by-principle*



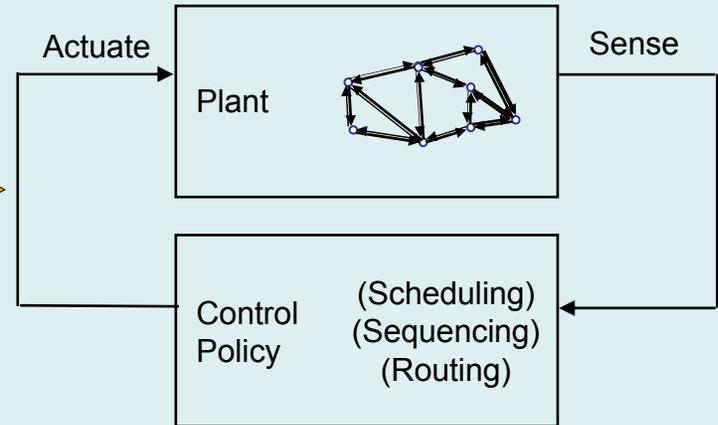
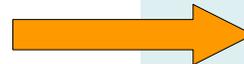
Major technical approaches:

- **Optimization-theoretic:** distributed optimal solution algorithm (economic interpretation)
- **Game-theoretic:** Nash equilibrium characterization and cooperative competition

## Optimality and adaptivity by design

Emerging "Optimization Decomposition" method:

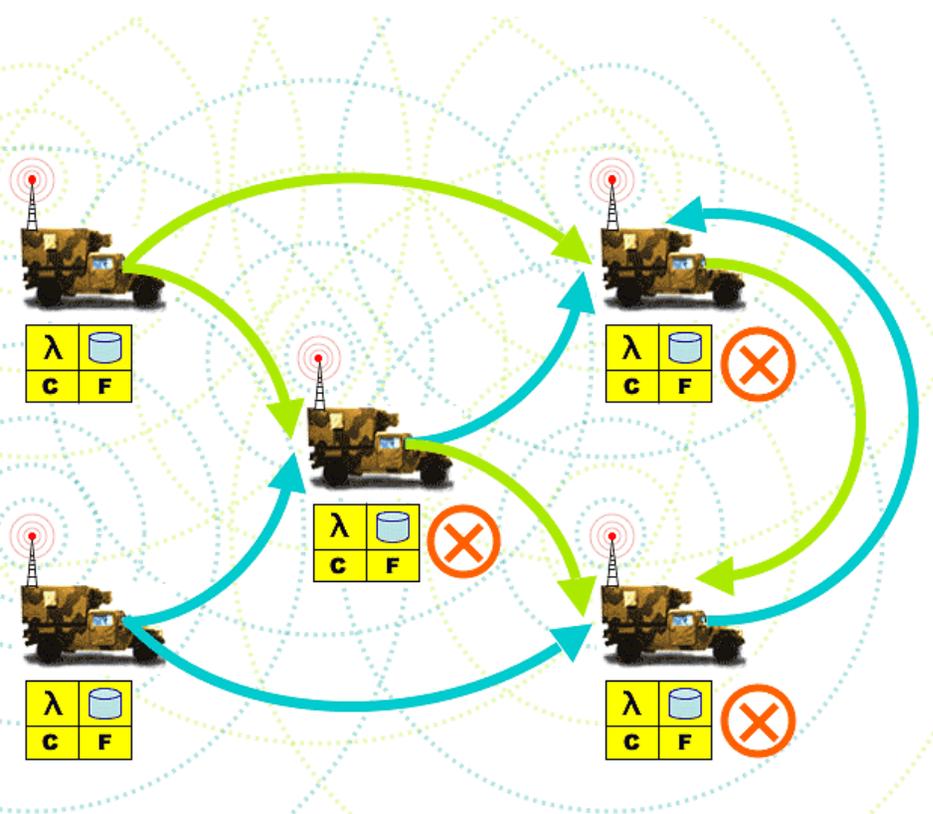
1. Formulate an optimization problem
2. Decompose optimization problem along horizontal (node) or vertical (network stack) lines such that each subproblem refers only to local variables
3. Couple the problems at runtime by passing joint "pricing" feedback appropriately



**Optimization decomposition maximally exploits the available physical radio capabilities**

**Optimization decomposition provides a scientific basis for network architecture**

# Candidate paradigm shift: From packets on links to *information on hyperarcs*



*Packet fragments are broadcast, mixed and recombined at each node until fully received*

## Summary Advantages of Network Coding:

- A unified theory of forward error correction (FEC), erasure coding, and multi-path routing offers robustness and simplicity
- Dense deployments are exploited by leveraging broadcast
- Heavy traffic loads are exploited with information-theoretic coding
- The information received by a node is stored and exploited later
- The same protocol handles unicast, multicast, and broadcast

IMAGE KEY			
	Copy		Forward
	Compute		Store
			Recombine

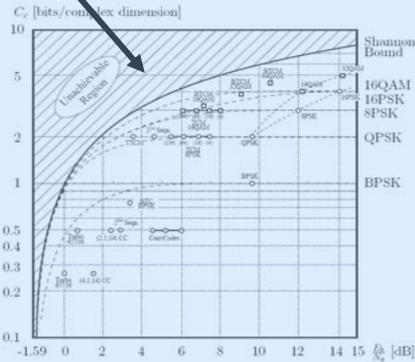
*Fragment/Package Pathways* (indicated by green arrows)

# ITMANET: A grand challenge in information theory

## FACTORS AFFECTING MANET CAPACITY

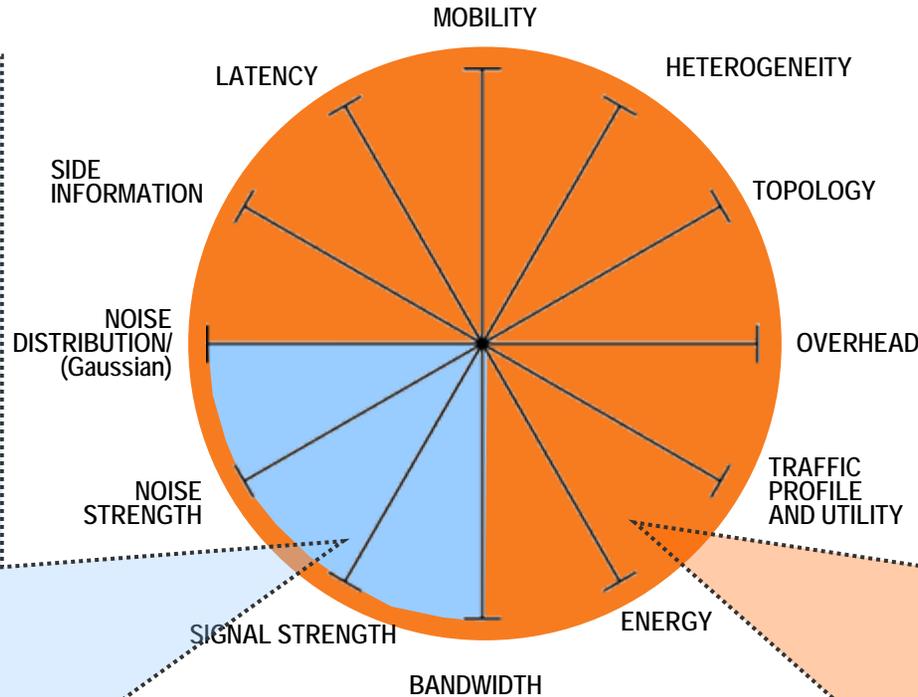
### Point-to-point communications:

For AWGN channels, an upper bound on capacity is known



This knowledge is represented by the AWGN channel capacity limit formula:

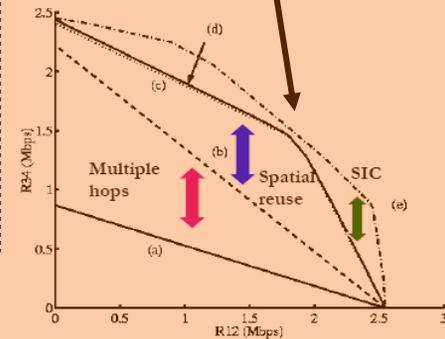
$$C = W \log_2 (1 + S/N) \text{ [bits/second]}$$



- Dimensions considered in Shannon formulation
- Dimensions considered in a future "unified theory of MANET Capacity"

### Wireless "network" communications:

For wireless networks, an upper capacity bound is not known except when assuming specific current technologies

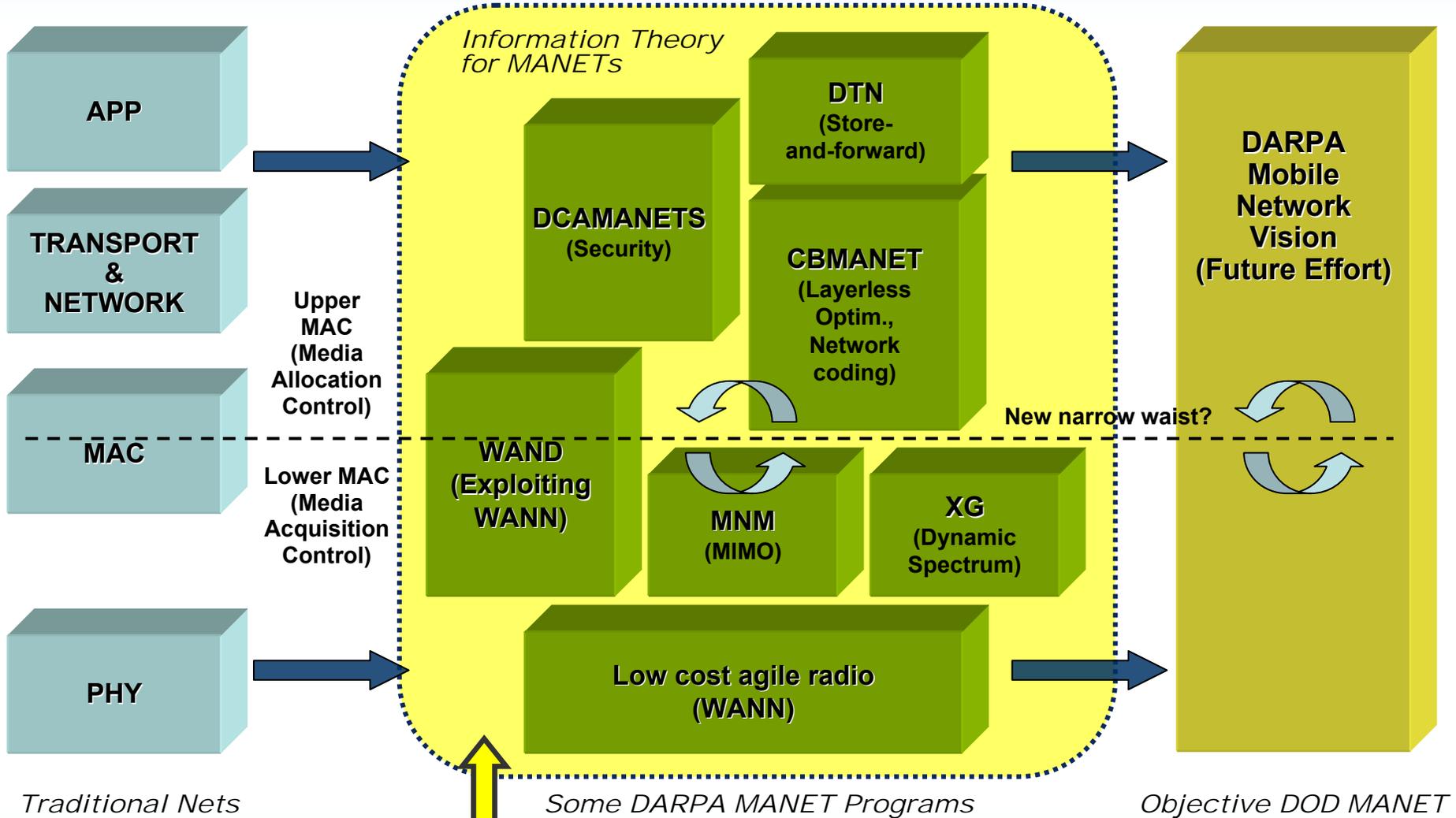


UNSOLVED Grand Challenge: Capacity Limits of MANETs

$$C = ??????????$$

**We seek a new kind of information theory powerful enough to describe MANET fundamental limits and tradeoffs**

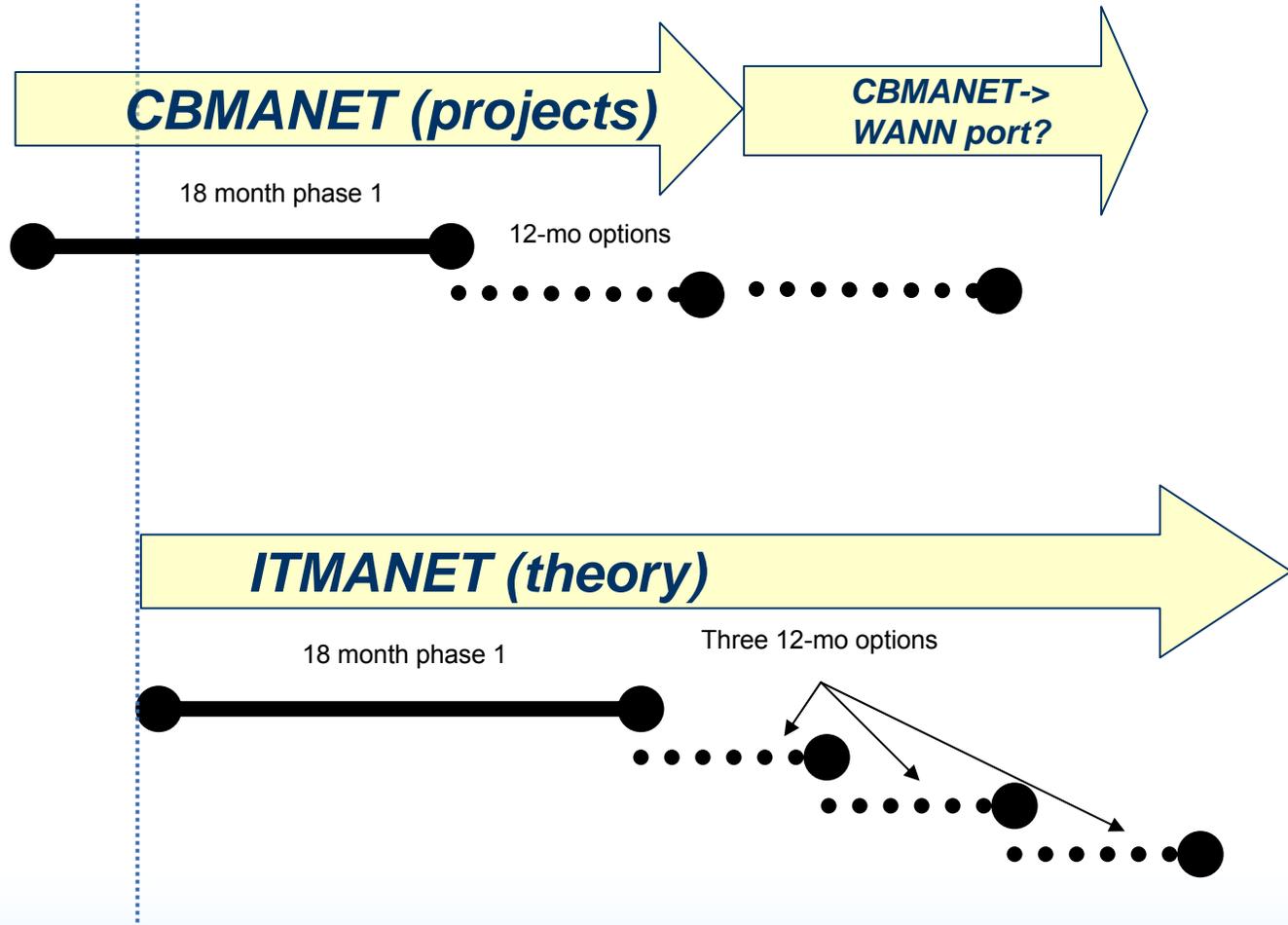
# Other paradigm shifts will emerge from better theory



**ITMANET: Theoretical foundations for a grand unification of DARPA program results (and more)**

# CBMANET & ITMANET program schedules

2006                      2007                      2008                      2009                      2010                      2011                      2012



Draft

**Initial results from both programs are promising**