

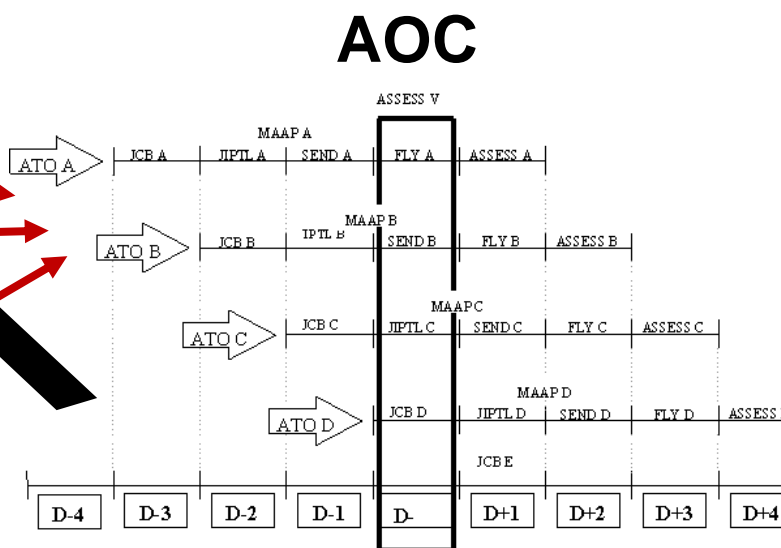
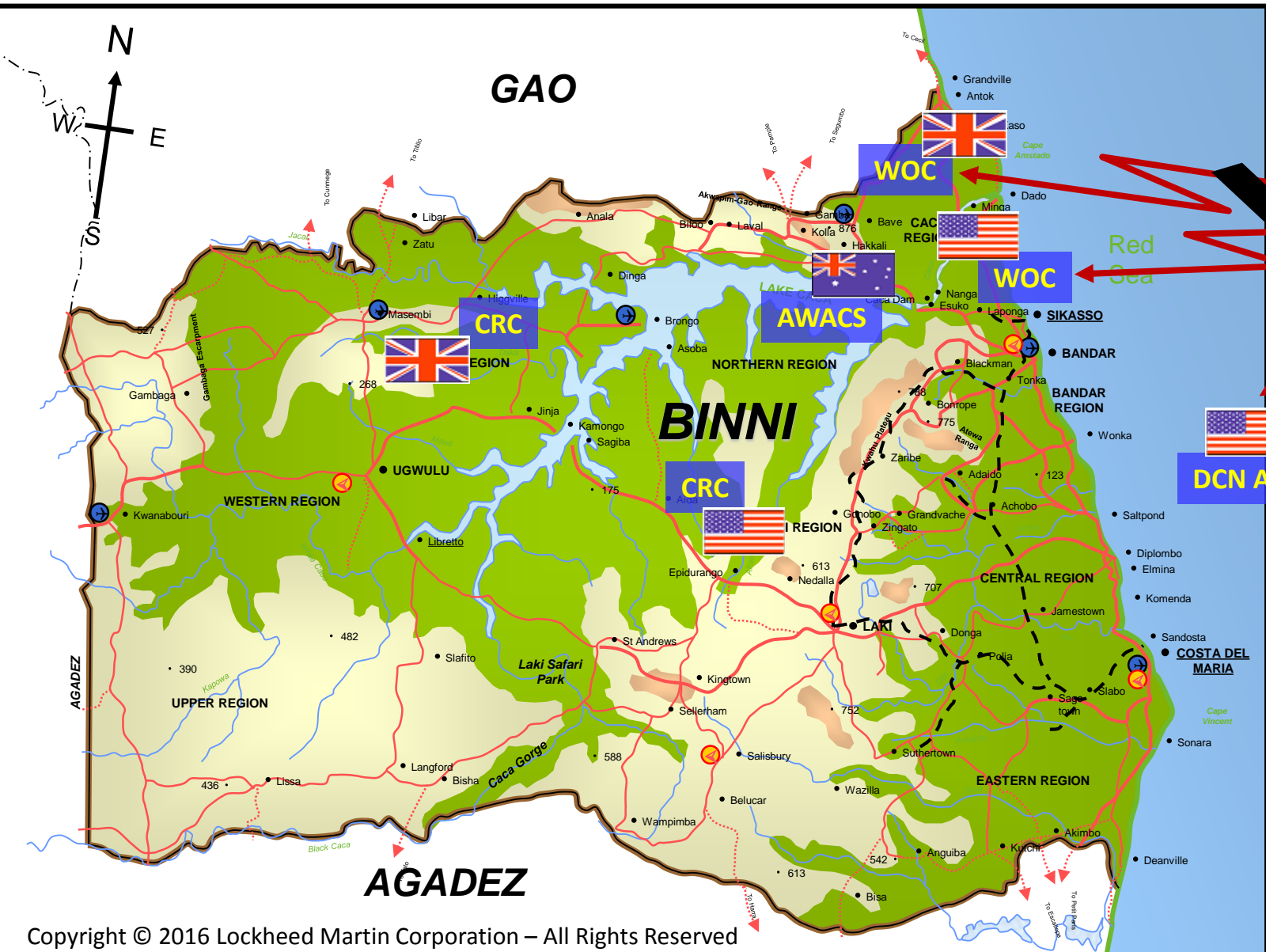
# Resilient C2 in the A2/AD Environment

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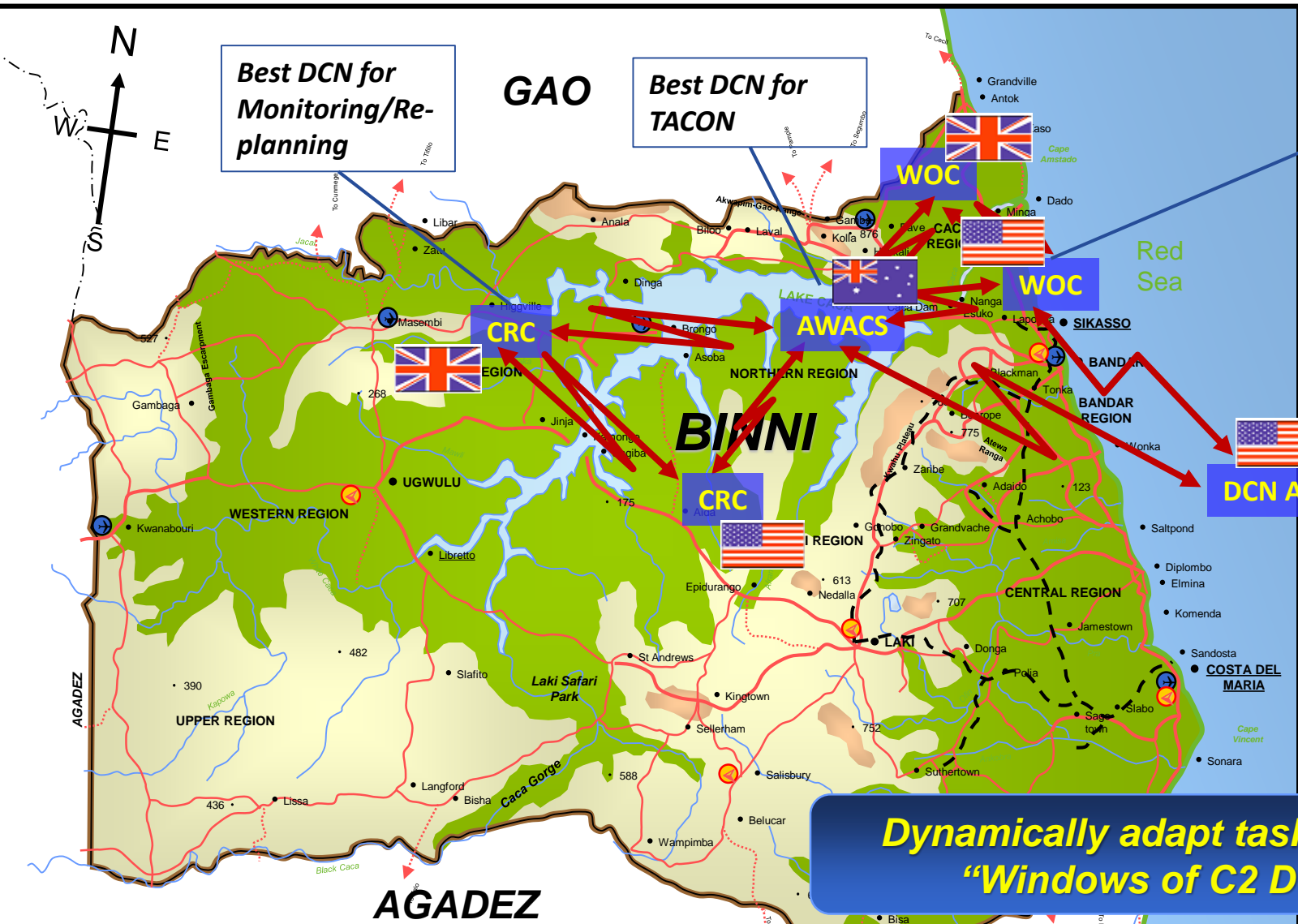
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# Problem: Reachback to AOC is Threatened



Binni scenario map from CoAX – Coalition Agents eXperiment <http://www.aiai.ed.ac.uk/project/coax/>

# Solution: Distributed Control



*Best DCN for Monitoring/Re-planning*

*Best DCN for TACON*

*Asset Provider, Reliable COMMs  
ISR links & Expertise*

*Best DCN to Plan Task(s), Assess Effects...*

*Distributed, forward C2 nodes take over AOC functions*

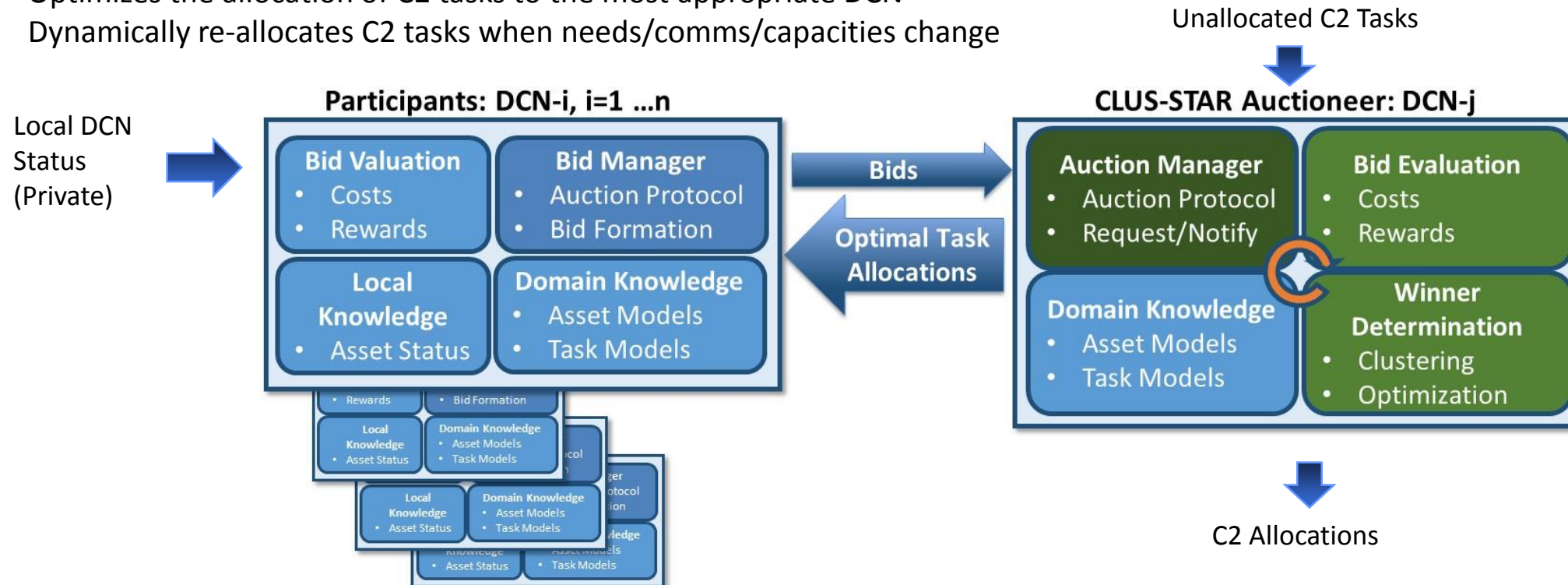
- *Plan, control, assess missions*
- *Question: which C2 node does what?*

***Dynamically adapt tasking and roles of DCNs, to achieve "Windows of C2 Dominance" in contested areas***



# Decision Support: Distributed Resource Allocation with *C2 Nodes as Resources*

- Optimizes the allocation of C2 tasks to the most appropriate DCN
- Dynamically re-allocates C2 tasks when needs/comms/capacities change



- “CLUS-STAR” Dynamic auction technique
- Result of IRAD and ONR investment

- Breaks allocation commitments in favor of higher-priority pop-up tasks
- Supports cooperation by multiple capabilities hosted on multiple platforms
- Low and very localized communications requirements

# Domain Independent Models

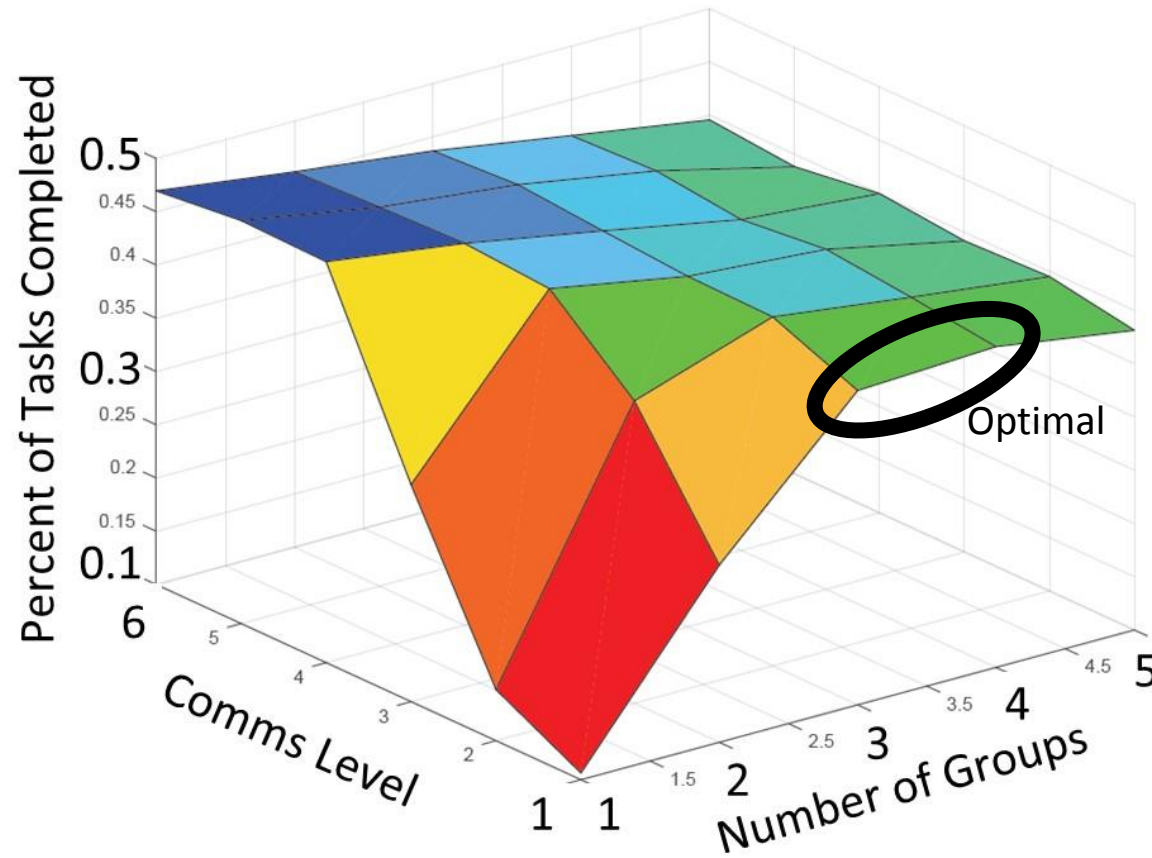


- **Tasks**
- Assets
- Capabilities/  
Proficiencies
- Rewards
- Priorities

- Task  $j$  is defined by  $(t_j, l_j, req_j, d_j, p_j, r_j, Pr_j, T_j, T_{0j})$ , where
  - $t_j \in \mathbb{R}_+$  is the release time of task  $j$
  - $l_j \in G$  is the location of task  $j$
  - $req_j \in \{0, 1\}^k$  is a  $k$ -vector of 0 or 1 describing the requirements for performing task  $j$  along  $k$  dimensions
  - $d_j \in \mathbb{R}_+^k$  is a  $k$ -vector time duration needs of task  $j$  along its  $k$  dimension requirements  $req_j$
  - $p_j \in \mathbb{R}_+$  is the penalty for not performing task  $j$
  - $r_j \in \mathbb{R}_+$  is the revenue associated with the completion of task  $j$
  - $Pr_j \in \mathbb{R}_+$  is the priority of task  $j$
  - $T_j \in \mathbb{R}_+$  is the deadline before task  $j$  has to be completed
  - $T_{0j} \in \mathbb{R}_+$  is the time task  $j$  is schedule to begin

Easy to apply to a variety of problems: IRS asset allocation, C2 task allocation, etc.

# Resilience to Intermittent Communications



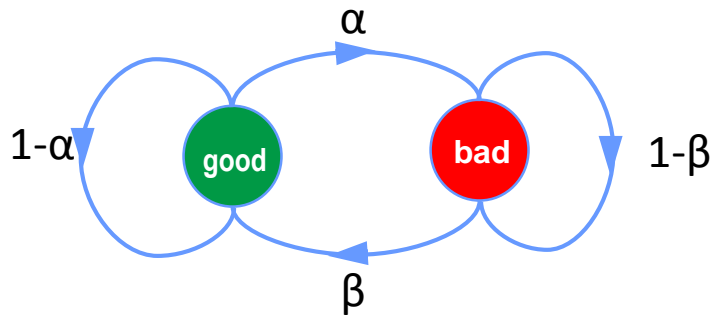
As communications degrade from perfect comms (Level 6) towards near total - 95% - loss (Level 1), the loss of SA and coordination messages favors the distributed algorithm over a centralized planner.

CLUS-STAR peer-to-peer solution is highly resilient to communications network degradation

# Communications Model



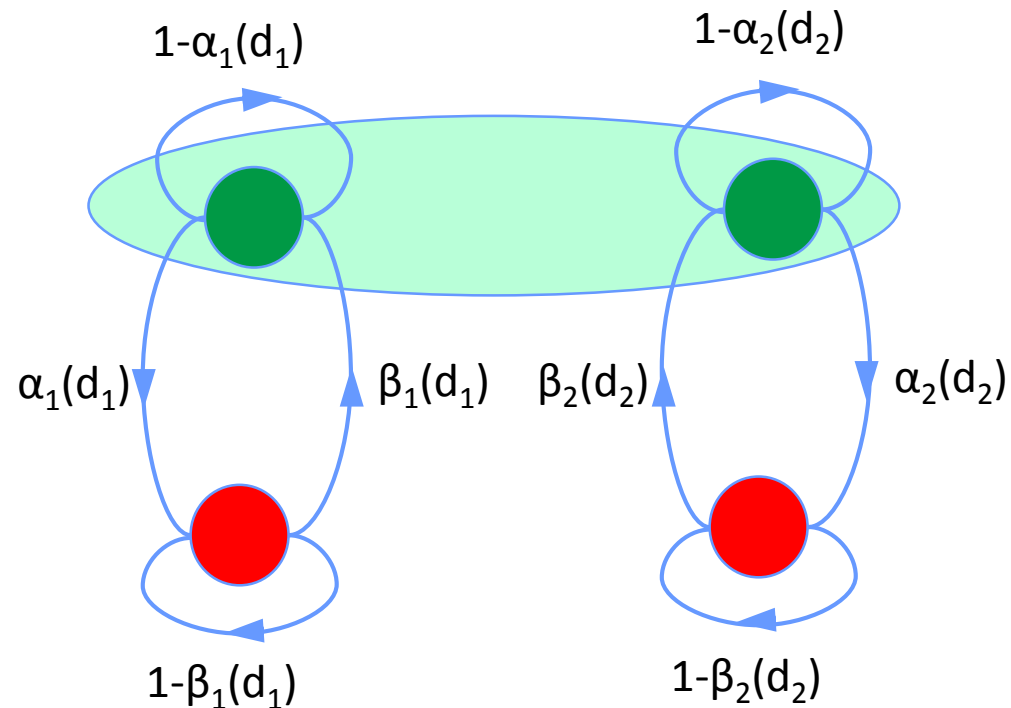
Two Stage Gilbert\_Elliott Channel



$\alpha$  and  $\beta$  are parameterized by distance

- Distance to the hot spots ( $d_1$ )
- Distance of communication ( $d_2$ )

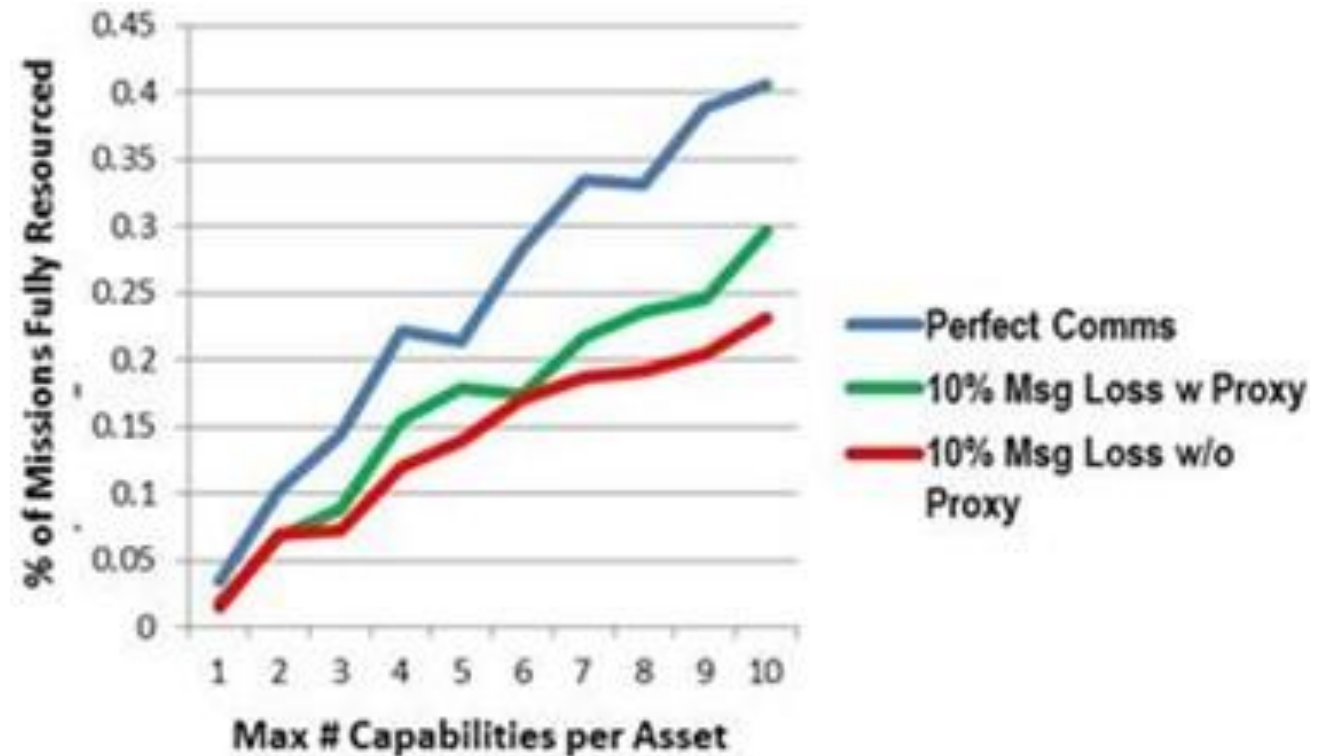
To be able to communicate with its peer, the agent must be in an compound good state. The agent will keep trying to send until success (delay) or time-out (failure)



# Algorithm Enhancements



- Anticipating change
  - Add a cost term that discounts the reward for assigning an asset to a task, if there is a high chance that the asset will be needed in the near future for a high priority mission
- Bidding Proxies bridge temporary disconnections
- Allocation by Percentage of a Resource







# Modeling: Nodes and Tasks

- **C2 Nodes (“Agents”)**
  1. **Disctributed C2 Node (DCN)**
  2. **Wing Operations Center (WOC)**
  3. **Control and Reporting Center**
  4. **DCGS Reachback Unit**
  5. **Target Reachback Unit**

- **Generic C2 Tasks**

Plan TST	Plan Strike	Plan CAS	Plan DCA
Control TST	Control Strike	Control CAS	Control DCA
Asses TST	Assess Strike	Assess CAS	Assess DCA

TST: Time-Sensitive Target

CAS: Close Air Support

DCA: Defensive Counter Air

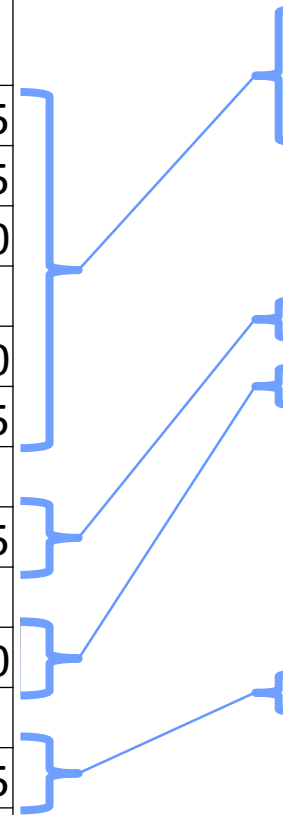
# Capability Requirements Matrices



## Task: Plan TST

Capability	Required? (Y/N)	% of Person
Approving authority	Yes	5
Ops Planner	Yes	25
ISR Planner	Yes	30
Spectrum Planner	No	
Airspace Control	Yes	10
PED GEOINT	Yes	15
Weather	Yes	5
Link-16	Yes	10
ROE	Yes	5

Capability	Required? (Y/N)	% of Person
Approving authority	Yes	5
Ops Planner	Yes	25
ISR Planner	Yes	30
Spectrum Planner	No	
Airspace Control	Yes	10
PED GEOINT	Yes	15
xxxxxxxxxxxxxx	No	
xxxxxxxxxxxxxx	Yes	15
xxxxxxxxxxxxxx	Yes	20
xxxxxxxxxxxxxx	Yes	5
xxxxxxxxxxxxxx	Yes	20
xxxxxxxxxxxxxx	Yes	5
xxxxxxxxxxxxxx	No	
xxxxxxxxxxxxxx	Yes	30
Weather	Yes	5
xxxxxxxxxxxxxx	No	
xxxxxxxxxxxxxx	Yes	30
Link-16	Yes	10
xxxxxxxxxxxxxx	No	
xxxxxxxxxxxxxx	Yes	25
xxxxxxxxxxxxxx	Yes	10
xxxxxxxxxxxxxx	No	
xxxxxxxxxxxxxx	No	
xxxxxxxxxxxxxx	No	
xxxxxxxxxxxxxx	No	
xxxxxxxxxxxxxx	No	
xxxxxxxxxxxxxx	Yes	15
xxxxxxxxxxxxxx	Yes	10
xxxxxxxxxxxxxx	Yes	20
ROE	Yes	5
xxxxxxxxxxxxxx	Yes	10
xxxxxxxxxxxxxx	Yes	30
xxxxxxxxxxxxxx	Yes	30
xxxxxxxxxxxxxx	Yes	30





# C2 Node Capabilities

Capability-People	#	Proficiency
Approving authority	2	1.0
Ops Planner	2	1.0
ISR Planner	0	1.0
Spectrum Planner	0	1.0
Airspace Control	0	1.0
PED GEOINT	0	1.0

Capability-Comms	Bool
VOIP	true
Link-16	true
UpChannel – AOC	false
Lateral - other C2	true
DownChannel – unit	false

Capability-Tools	Bool
Chat	true
AOI Coverage (Radar/COP/etc.)	false
ROE	true
ATO	true
No Strike List	True

**WOC (partial list)**

# Scenario

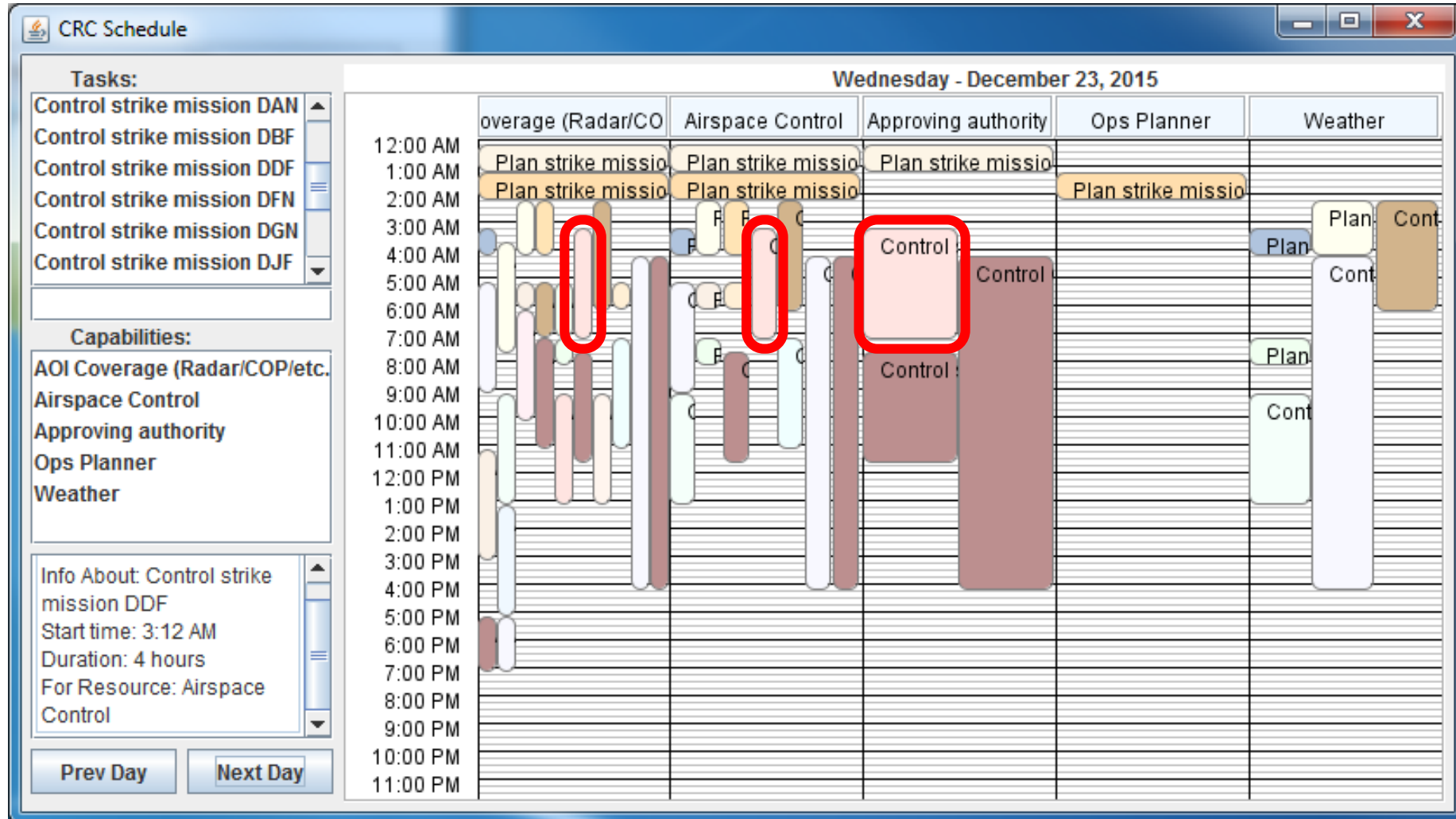


Plan strike mission DAN – required by 1500 20 Oct 2020, typical C2 task duration 1 hour, priority 3  
Control strike mission DAN – required by 1700 20 Oct 2020, typical C2 task duration 4 hours, priority 2  
Assess strike mission DAN – required by 2100 20 Oct 2020, typical C2 task duration 4 hours, priority 2  
Plan strike mission DBF – required by 1200 20 Oct 2020, typical C2 task duration 1 hour, priority 3  
Control strike mission DBF – required by 1400 20 Oct 2020, typical C2 task duration 4 hours, priority 2  
Assess strike mission DBF – required by 1800 20 Oct 2020, typical C2 task duration 4 hours, priority 2  
Plan strike mission DDF – required by 1300 20 Oct 2020, typical C2 task duration 1 hour, priority 3  
Control strike mission DDF – required by 1500 20 Oct 2020, typical C2 task duration 4 hours, priority 2  
Assess strike mission DDF – required by 1900 20 Oct 2020, typical C2 task duration 4 hours, priority 2  
...  
Plan strike mission DIF – required by 0930 20 Oct 2020, typical C2 task duration 1 hour, priority 3  
Control strike mission DIF – required by 1130 20 Oct 2020, typical C2 task duration 4 hours, priority 2  
Assess strike mission DIF – required by 1530 20 Oct 2020, typical C2 task duration 4 hours, priority 2  
Plan CAS mission 1 – required by 0200 20 Oct 2020, typical C2 task duration 2 hours, priority 3  
Control CAS mission 1 – required by 0400 20 Oct 2020, typical C2 task duration 12 hours, priority 2  
Assess CAS mission 1 – required by 1700 20 Oct 2020, typical C2 task duration 2 hours, priority 2  
...  
Plan DCA mission 1 – required by 0200 20 Oct 2020, typical C2 task duration 2 hours, priority 3  
Control DCA mission 1 – required by 0400 20 Oct 2020, typical C2 task duration 12 hours, priority 2  
Assess DCA mission 1 – required by 1700 20 Oct 2020, typical C2 task duration 2 hours, priority 2  
...

# GUI: Allocations for one C2 Node



CRC



# Capabilities Allocated for “Control Strike DDF”



WOC

WOC/WPC Schedule

Tasks: Assess strike mission DDF, Assess strike mission DFN, Assess strike mission DGN, Control strike mission DAN, Control strike mission DBF, Control strike mission DDF, Control strike mission DFN, Control strike mission DGN

Capabilities: Approving authority, Joint Tactical Information Dist, Ops Planner, TST Matrix (approval authority), Targeteer, Weather

Details

Prev Day Next Day

Time	Task	Capability
12:00 AM		
1:00 AM		
2:00 AM		
3:00 AM		
4:00 AM	Control strike mission DDF	Control strike mission DDF
5:00 AM	Control strike mission DDF	Control strike mission DDF
6:00 AM		
7:00 AM		
8:00 AM		
9:00 AM		
10:00 AM		
11:00 AM		
12:00 PM		
1:00 PM		
2:00 PM		
3:00 PM		
4:00 PM		
5:00 PM		
6:00 PM		
7:00 PM		
8:00 PM		
9:00 PM		
10:00 PM		
11:00 PM		

DCGS Reachback

DCGS Reachback Unit Schedule

Tasks: Assess strike mission DAN, Assess strike mission DBF, Assess strike mission DDF, Assess strike mission DFN, Assess strike mission DGN, Control strike mission DAN, Control strike mission DBF, Control strike mission DDF

Capabilities: CDE like capability (DCIDE), Chat, DownChannel - unit, Intel (Ground and air threats), Lateral - other C2, Link-16, PED GEOINT, PED SIGINT

Details

Prev Day Next Day

Time	Task	Capability	Capability	Capability	Capability	Capability	Capability
12:00 AM							
1:00 AM							
2:00 AM							
3:00 AM							
4:00 AM	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF
5:00 AM	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF
6:00 AM							
7:00 AM							
8:00 AM							
9:00 AM							
10:00 AM							
11:00 PM							

DCN

DCN (GUAM) Schedule

Tasks: Assess strike mission DAN, Assess strike mission DBF, Assess strike mission DDF, Assess strike mission DFN, Assess strike mission DGN, Control strike mission DAN, Control strike mission DBF, Control strike mission DDF

Capabilities: Approving authority, ISR Planner, Ops Planner, Spectrum Planner, Weather

Details

Prev Day Next Day

Time	Task	Capability	Capability
12:00 AM		ISR Planner	Weather
1:00 AM			
2:00 AM			
3:00 AM			
4:00 AM	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF
5:00 AM	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF
6:00 AM			
7:00 AM			
8:00 AM			
9:00 AM			
10:00 AM			
11:00 AM			

CRC

CRC Schedule

Tasks: Assess strike mission DAN, Assess strike mission DBF, Assess strike mission DDF, Assess strike mission DFN, Assess strike mission DGN, Control strike mission DAN

Capabilities: AOI Coverage (Radar/COP/etc.), Airspace Control, Approving authority, Ops Planner, Weather

Info About: Control strike mission DDF, Start time: 3:12 AM, Duration: 4 hours, For Resource: AOI Coverage (Radar/COP/etc.)

Details

Prev Day Next Day

Time	Task	Capability	Capability	Capability
12:00 AM		AOI Coverage (Radar/COP/etc.)	Airspace Control	Approving authority
1:00 AM				
2:00 AM				
3:00 AM				
4:00 AM	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF
5:00 AM	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF	Control strike mission DDF
6:00 AM				
7:00 AM				
8:00 AM				
9:00 AM				
10:00 AM				
11:00 PM				

# Future Work



- **Validate end user value proposition**
  - **Start by gathering SME feedback on the current design**
  - **Expose the concept to a set of operational users**
  - **Specify a richer set of user interaction beyond inspection of automated results**
  - **Prototype an interactive user interface**
- **Extensions**
  - **Design and implement conditional resource requirements, e.g., when allocation of a task across two nodes requires a higher level of communications capability between the two nodes.**
  - **Predictive modeling of denial actions (jamming, kinetic attack, cyber attack, spoofing, etc.) to enable proactive task re-allocation**
  - **Mixed-initiative allocation**