



Air Force Institute of Technology



Mission-Related Execution and Planning Through Quality of Service Methods

**15th International Command and Control Research and
Technology Symposium**
Santa Monica, CA June 22-24, 2010

Major Vinod Naga, USAF

John Colombi, PhD

Michael Grimaila, PhD

Kenneth Hopkinson, PhD



Air Force Institute of Technology
Wright Patterson AFB, OH



sponsored by AFRL/IFE and AFRL/IFG, Rome, NY



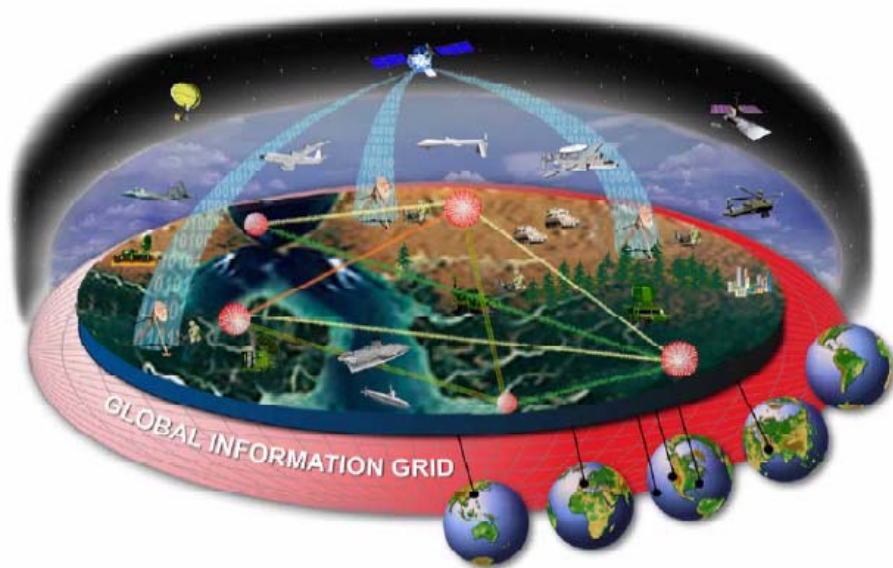


Outline



Focus on decomposition of missions followed by network resource allocation by mission area through Quality of Service (QoS) methods.

- Mission Organization and Decomposition
- Quality of Service (QoS)
- Mission-Oriented QoS Performance
- Mission QoS Experiment
 - Setup
 - Performance Requirements
 - Rates and Priorities
 - Value
- Next Steps
- Summary



"...possibly the single-most transforming thing in our forces will not be a weapons system, but a set of interconnections and a substantially enhanced capability because of that awareness."

Former U.S. Secretary of Defense, Donald Rumsfeld

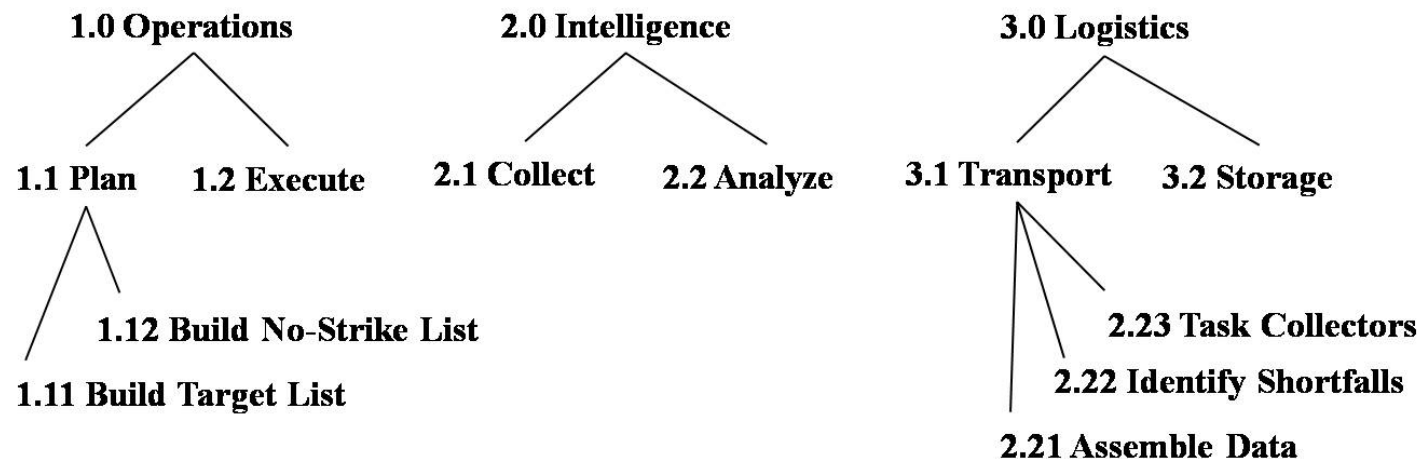


Mission Organization and Decomposition



Mission	Submission	SubSubmission
Operations		
Operations	Plan	
Operations	Plan	Build Target List
Operations	Plan	Build No-Strike List
Intelligence		
Intelligence	Collection	
Intelligence	Collection	Build Collection Plan
Intelligence	Analysis	
Intelligence	Analysis	Assemble Data
Intelligence	Analysis	Identify Shortfalls
Intelligence	Analysis	Task Collectors
Logistics		
Logistics	Transportation	
Logistics	Storage	

- Functional Allocation
- Complex Activities
- Organizational Relationship
- Method for Strategy to Task





Quality of Service



- Resource reservations
- Priority for apps, users, data flows
- Specific performance
- vs. best-effort and over-provisioning
- Service Level Agreement (SLA)
- Monitored, maintained, managed
 - QoS may refer to the measure
 - Intserv – per flow (RSVP)
 - Diffserv – per class (DSCP)
 - Traffic Shaping and Scheduling techniques
- Device capability
- Service-Oriented Architecture (SOA) view





- Resource Reservation
- How Signaling Transferred
- Coupling with Routing/Forwarding Method
- State of Resource Management
- Required Participation





QoS Key Parameters Example (1 of 2)



DSCP: - class-based QoS protocol
- based on differentiated services (DIFFSERV) model

Key Parameters	Implementation
Resource Reservation	<p>Class</p> <ul style="list-style-type: none">• best-effort• assured-forward & drop priority• expedited forwarding <p>Assignment</p> <ul style="list-style-type: none">• distinct (to meet committed access rate)• shared (group)
How Signaling Transferred	<p>Header</p> <ul style="list-style-type: none">• Type of Service (ToS)• DiffServe (DS) field <p>Communicants</p> <ul style="list-style-type: none">• originator & destination• Intermediates for per-hop <p>Maintenance</p> <ul style="list-style-type: none">• queued by class• weighted queues• class-based policing• metering



QoS Key Parameters Example (2 of 2)



DSCP: - class-based QoS protocol
- based on differentiated services (DIFFSERV) model

Key Parameters	Implementation
Routing Coupling	Per-Hop Behavior in DSCP class
Resource Management State	Soft in all nodes, random early detection, congestion avoidance
Required Participation	None – but need all nodes in path for performance assurances



Origins and Directions



- SERVQUAL: - developed by Zeithaml, Parasuraman, Berry
 - measure how service organizations meet customer needs





Mission-Oriented QoS Performance



- SERVQUAL: - developed by Zeithaml, Parasuraman, Berry
 - measure how service organizations meet customer needs
- QoS: maintaining circuit-switched telephony – transitioned to IP QoS.
- QoE: user perception of product quality and utility.

Service Quality SERVQUAL	Quality of Experience QoE	Quality of Service QoS
<ul style="list-style-type: none">▪ Tangibles▪ Reliability▪ Responsiveness▪ Competence▪ Courtesy▪ Credibility▪ Feel Secure▪ Access▪ Communication▪ Understanding the Customer	<ul style="list-style-type: none">▪ Usefulness▪ Happiness▪ Satisfaction▪ Worthwhile▪ Expected	<ul style="list-style-type: none">▪ Delay▪ Jitter▪ Dropped Packet Rate▪ Packet Error Rate▪ Throughput



Mission-Oriented QoS Performance



- SERVQUAL: - developed by Zeithaml, Parasuraman, Berry
 - measure how service organizations meet customer needs
- QoS: maintaining circuit-switched telephony – transitioned to IP QoS.
- QoE: user perception of product quality and utility.

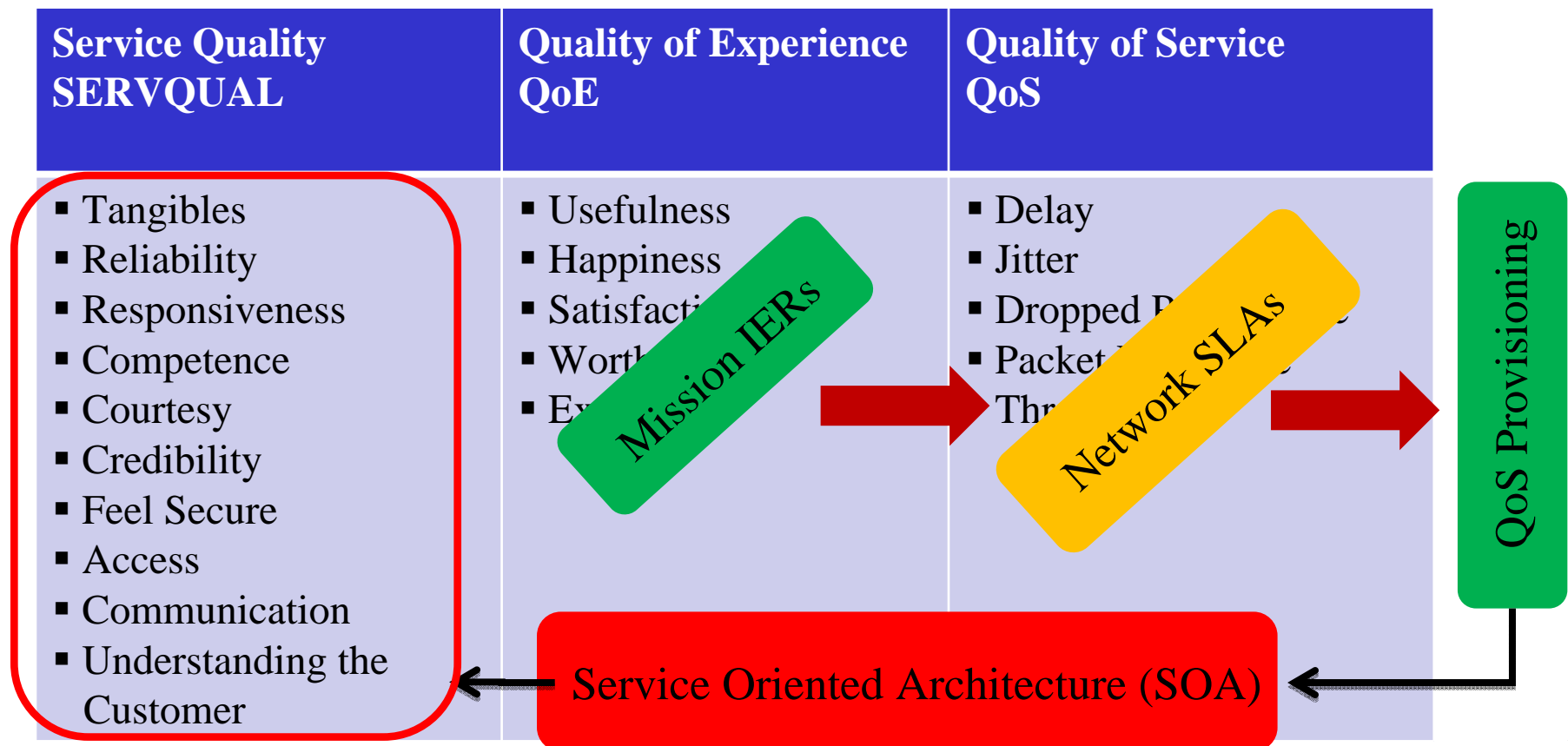




Mission-Oriented QoS Performance

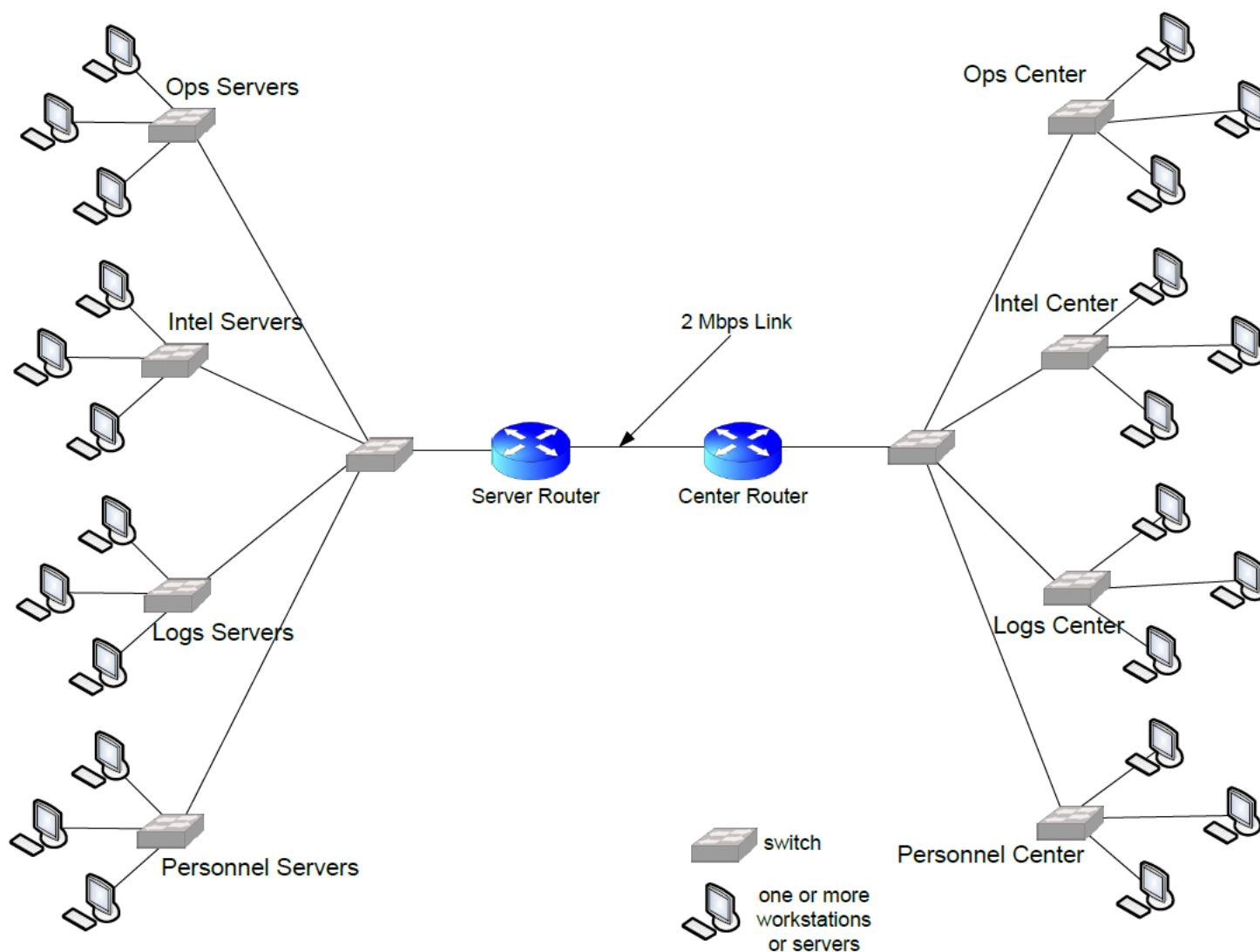


- SERVQUAL: - developed by Zeithaml, Parasuraman, Berry
 - measure how service organizations meet customer needs
- QoS: maintaining circuit-switched telephony – transitioned to IP QoS.
- QoE: user perception of product quality and utility.





Mission QoS Experiment Setup





Campaign Phases



Campaign Phase:	Equal	Logistics	Operations	Intelligence
Priority 1	All Mission Areas	Logs	Ops	Intel
Priority 2		Intel	Intel	Ops
Priority 3		Ops	Logs	Logs
Priority 4		Personnel	Personnel	Personnel

Priorities of Mission Areas for each Campaign Phase



IER Requirements



Campaign Phase:	Equal	Logistics	Operations	Intelligence
Priority 1	All Mission Areas	Logs	Ops	Intel
Priority 2		Intel	Intel	Ops
Priority 3		Ops	Logs	Logs
Priority 4		Personnel	Personnel	Personnel

Priorities of Mission Areas for each Campaign Phase

Campaign Phase:	Equal	Logistics	Operations	Intelligence
IER 1	Ops traffic: 300 kbps	Pre-combat logistical staging	Ops command and control	Streaming ISR feeds
IER 2	Intel traffic: 300 kbps	Real-time intel updates	Real-time intel updates	Ops command and control
IER 3	Logs traffic: 300 kbps	Pre-staging ops plans	Ops support logistics	Ops support logistics
IER 4	Pers traffic: 300 kbps	Health and wellness info	Health and wellness info	Health and wellness info

Information Exchange Requirements for each Campaign Phase



SLA for Phases



Campaign Phase:	Equal	Logistics	Operations	Intelligence
Priority 1	All Mission Areas	Logs	Ops	Intel
Priority 2		Intel	Intel	Ops
Priority 3		Ops	Logs	Logs
Priority 4		Personnel	Personnel	Personnel

Priorities of Mission Areas for each Campaign Phase

Campaign Phase:	Equal	Logistics	Operations	Intelligence
IER 1	Ops traffic: 300 kbps	Pre-combat logistical staging	Ops command and control	Streaming ISR feeds
IER 2	Intel traffic: 300 kbps	Real-time intel updates	Real-time intel updates	Ops command and control
IER 3	Logs traffic: 300 kbps	Pre-staging ops plans	Ops support logistics	Ops support logistics
IER 4	Pers traffic: 300 kbps	Health and wellness info	Health and wellness info	Health and wellness info

Information Exchange Requirements for each Campaign Phase

Campaign Phase:	Equal	Logistics	Operations	Intelligence
SLS1	Ops traffic: 300 kbps	Logs End-to-End delay < 0.1 sec	Ops E-to-E delay < 0.1 sec	Intel E-to-E delay < 0.1 sec
SLS2	Intel traffic: 300 kbps	Logs traffic received > 95%	Ops pkt delay variance < 0.2	Intel pkt delay variance < 0.1
SLS3	Logs traffic: 300 kbps	Ops End-to-End delay < 0.3 sec	Ops traffic received > 99%	Intel traffic received > 99%
SLS4	Pers traffic: 300 kbps	Intel End-to-End delay < 0.3 sec	Intel E-to-E delay < 0.1 sec	Ops E-to-E delay < 0.2 sec
SLS5		Personnel traffic received > 50%	Intel traffic received > 80%	Ops pkt delay variance < 0.3
SLS6			Logs traffic received > 50%	Ops traffic received > 99%
SLS7			Pers. traffic received > 20%	Logs traffic received > 25%
SLS8				Pers. traffic received > 20%

Service Level Agreement with Specifications for each Campaign Phase

Rates and Priorities



ion config. mission	equal equal	equal logs	logs logs	ops logs	ops ops	intel ops	intel intel	
ons flowrate (kbps)	300 1	300 3	500 3	1400 3	1400 1	1400 1	1400 2	configured priority operations
nce flowrate (kbps)	300 1	300 2	50 2	50 2	50 2	500 2	500 1	configured priority intelligence
cs flowrate (kbps)	300 1	300 1	1600 1	800 1	800 3	800 3	800 3	configured priority logistics
nel flowrate (kbps)	300 1	300 4	50 4	50 4	50 4	50 4	50 4	configured priority personnel

and Priorities of Mission Areas for each Campaign Phase

Rates and Priorities



ion config. mission	equal equal	equal logs	logs logs	ops logs	ops ops	intel ops	intel intel	
ons flowrate (kbps)	300 1	300 3	500 3	1400 3	1400 1	1400 1	1400 2	configured priority operations
nce flowrate (kbps)	300 1	300 2	50 2	50 2	50 2	500 2	500 1	configured priority intelligence
cs flowrate (kbps)	300 1	300 1	1600 1	800 1	800 3	800 3	800 3	configured priority logistics
nel flowrate (kbps)	300 1	300 4	50 4	50 4	50 4	50 4	50 4	configured priority personnel

and Priorities of Mission Areas for each Campaign Phase

ssion config. mission	equal equal	equal logs	logs logs	ops logs	ops ops	intel ops	intel intel
on flow (kbps)	1200	1200	2200	2300	2300	2750	2750
itized flows (kbps)	1712	1712	2712	2812	2812	3262	3262
kbps)	2512	2512	3512	3612	3612	4062	4062
eeded by pri.	-14%	-14%	36%	41%	41%	63%	63%
eeded by all	26%	26%	76%	81%	81%	103%	103%

and links active: Rates of prioritized and non-prioritized traffic with link usage

Rates and Priorities



mission config. mission	equal equal	equal logs	logs logs	ops logs	ops ops	intel ops	intel intel	
ons flowrate (kbps)	300 1	300 3	500 3	1400 3	1400 1	1400 1	1400 2	configured priority operations
nce flowrate (kbps)	300 1	300 2	50 2	50 2	50 2	500 2	500 1	configured priority intelligence
cs flowrate (kbps)	300 1	300 1	1600 1	800 1	800 3	800 3	800 3	configured priority logistics
nel flowrate (kbps)	300 1	300 4	50 4	50 4	50 4	50 4	50 4	configured priority personnel

and Priorities of Mission Areas for each Campaign Phase

mission config. mission	equal equal	equal logs	logs logs	ops logs	ops ops	intel ops	intel intel
on flow (kbps)	1200	1200	2200	2300	2300	2750	2750
tized flows (kbps)	1712	1712	2712	2812	2812	3262	3262
(kbps)	2512	2512	3512	3612	3612	4062	4062
eeded by pri.	-14%	-14%	36%	41%	41%	63%	63%
eeded by all	26%	26%	76%	81%	81%	103%	103%

hand links active: Rates of prioritized and non-prioritized traffic with link usage

	equal-equal	equal-logs	logs-logs	ops-logs	ops-ops	intel-ops	intel-intel
	100%	100%	0%	42%	100%	100%	60%
	100%	100%	4%	100%	95%	15%	100%
	100%	100%	92%	100%	5%	0%	0%
	100%	99%	0%	0%	0%	0%	0%

Rates and Priorities



mission config. mission	equal equal	equal logs	logs logs	ops logs	ops ops	intel ops	intel intel	
ons flowrate (kbps)	300	300	500	1400	1400	1400	1400	configured priority operations
nce flowrate (kbps)	300	300	50	50	50	500	500	configured priority intelligence
cs flowrate (kbps)	300	300	1600	800	800	800	800	configured priority logistics
nel flowrate (kbps)	300	300	50	50	50	50	50	configured priority personnel

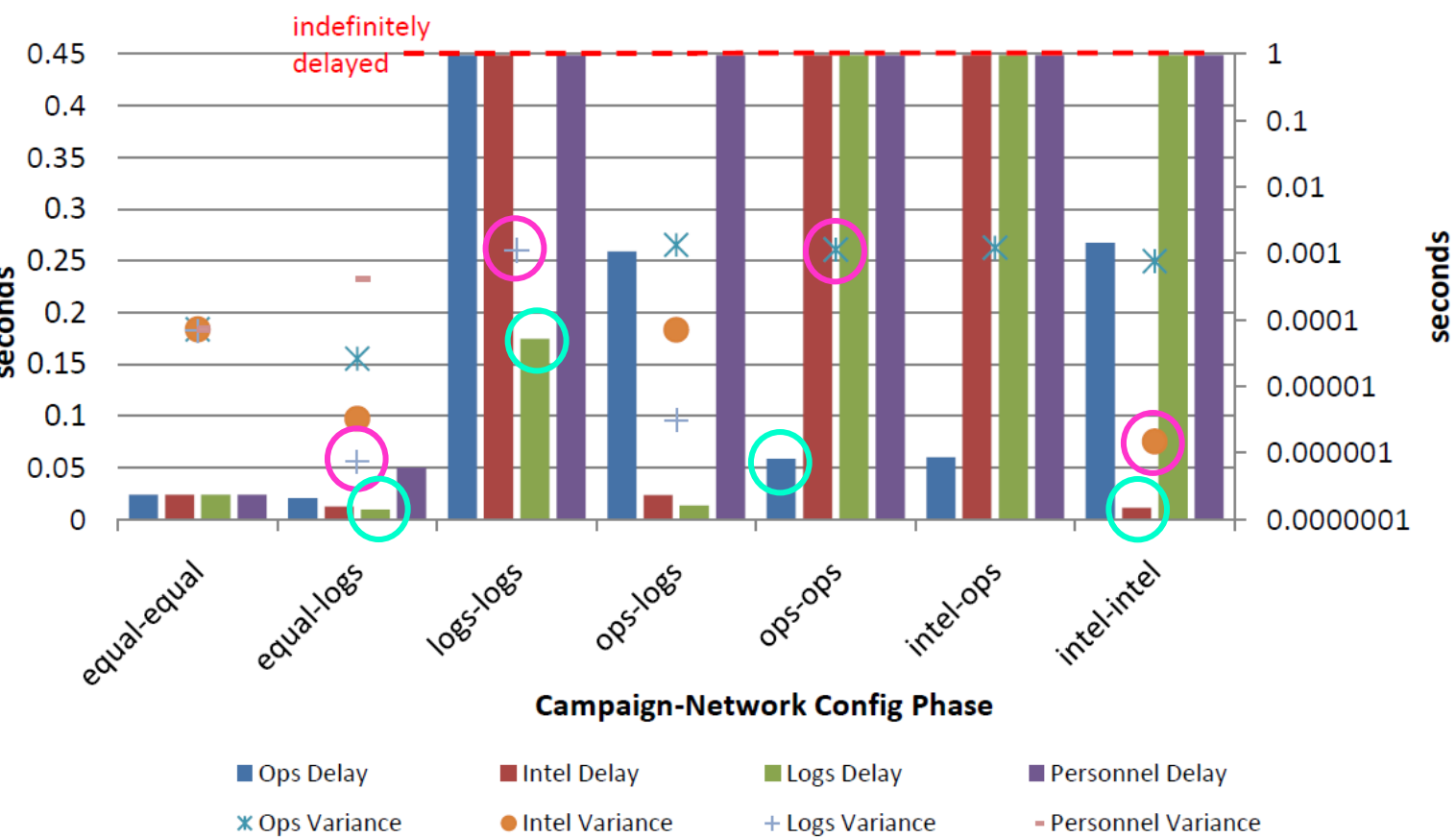
and Priorities of Mission Areas for each Campaign Phase

mission config. mission	equal equal	equal logs	logs logs	ops logs	ops ops	intel ops	intel intel
on flow (kbps)	1200	1200	2200	2300	2300	2750	2750
tized flows (kbps)	1712	1712	2712	2812	2812	3262	3262
(kbps)	2512	2512	3512	3612	3612	4062	4062
eeded by pri.	-14%	-14%	36%	41%	41%	63%	63%
eeded by all	26%	26%	76%	81%	81%	103%	103%

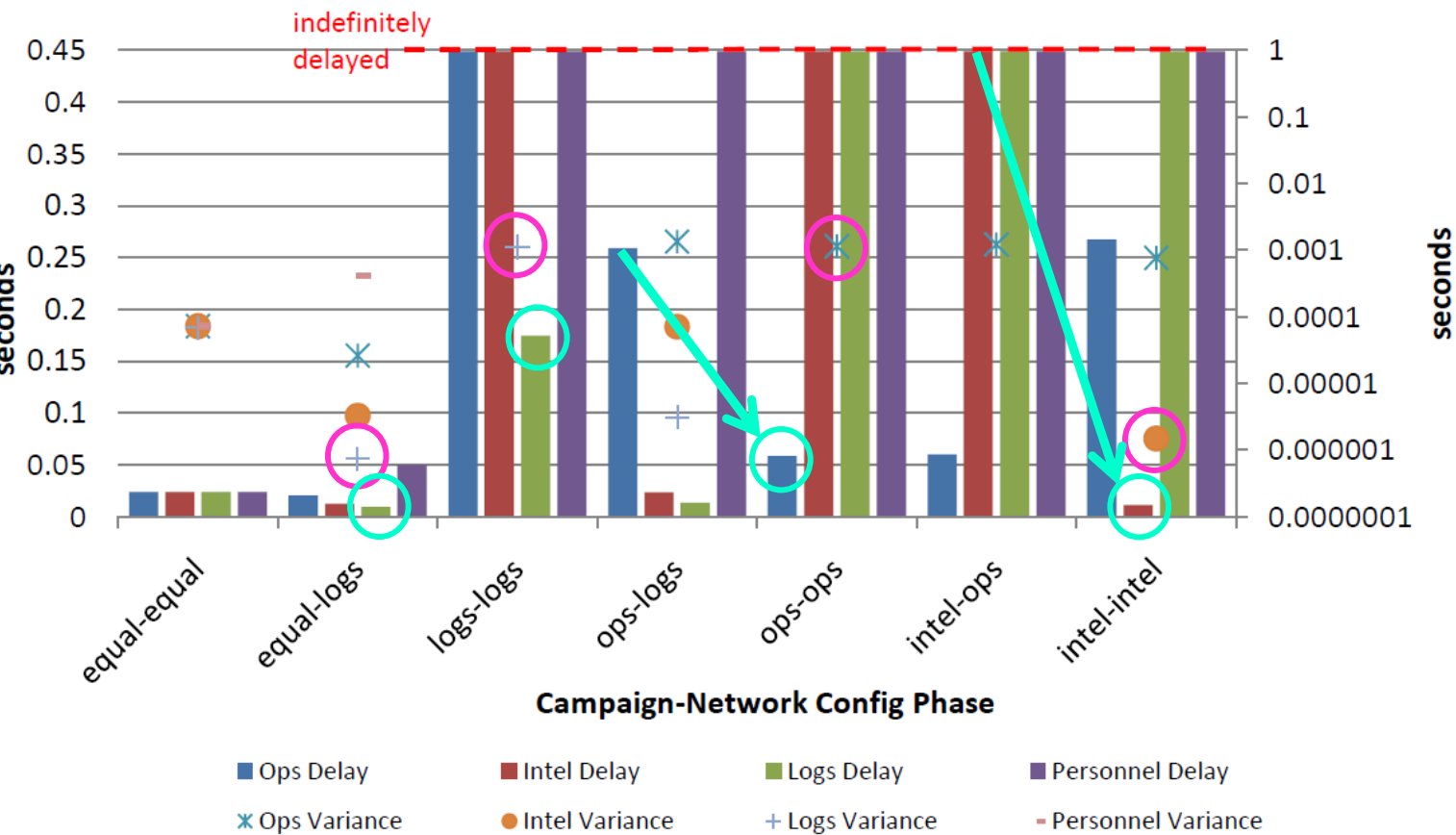
and links active: Rates of prioritized and non-prioritized traffic with link usage

equal-equal	equal-logs	logs-logs	ops-logs	ops-ops	intel-ops	intel-intel
100%	100%	0%	42%	100%	100%	60%
100%	100%	4%	100%	95%	15%	100%
100%	100%	92%	100%	5%	0%	0%
100%	99%	0%	0%	0%	0%	0%

Delay and Jitter



Delay and Jitter



Configuring network to campaign phase improves delay and jitter



Value



M mission areas

$$\sum_{m=1}^M c \omega^a_m N_{mv}$$

delivered value for

campaign-phase c

normalizing constant

weighted priority level

priority of mission area m

numb. packets delivered

for mission area m



Value

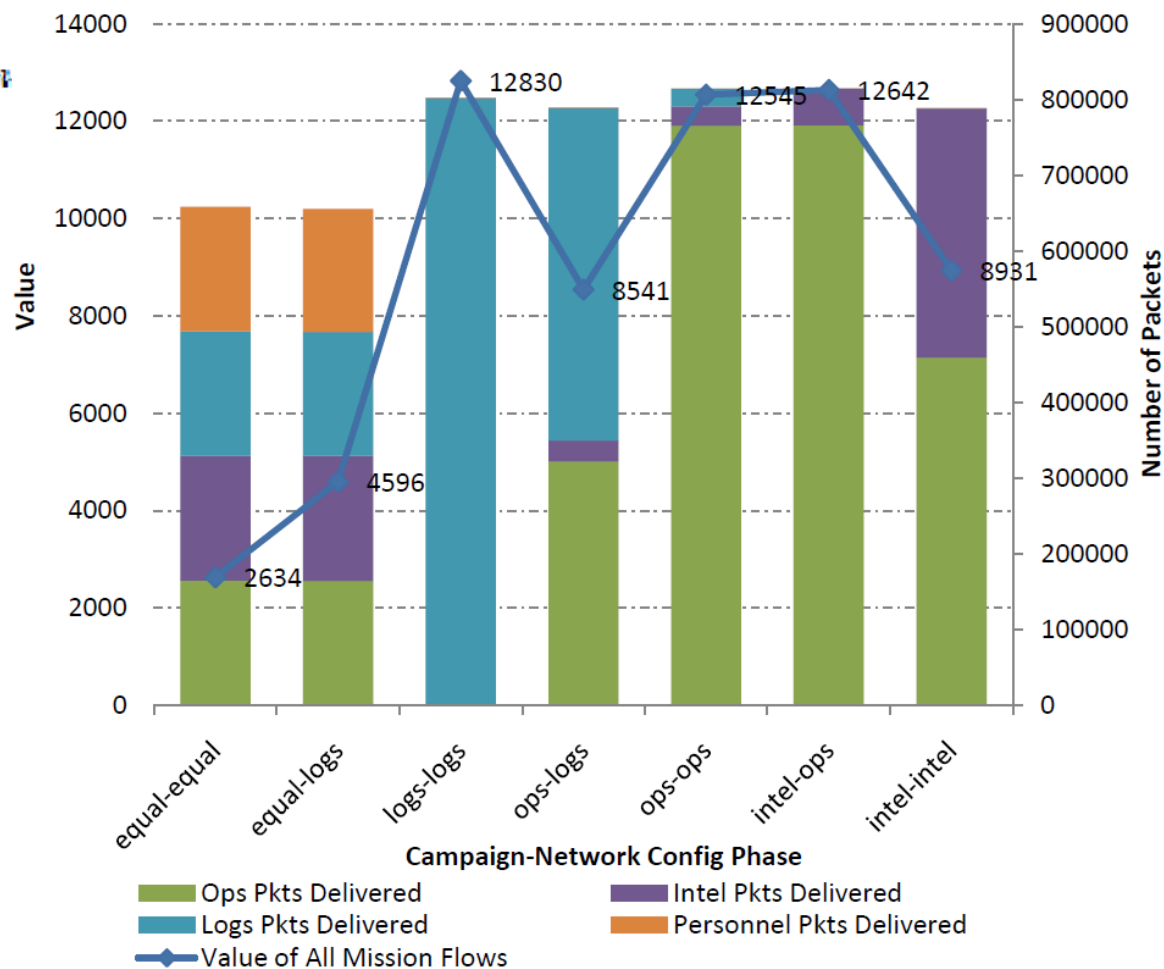


M mission areas

$$\sum_{m=1}^M$$

$$C \omega^a N_m$$

Value delivered for
campaign-phase c
normalizing constant
weighted priority level
priority of mission area m
num. packets delivered
for mission area m



Value



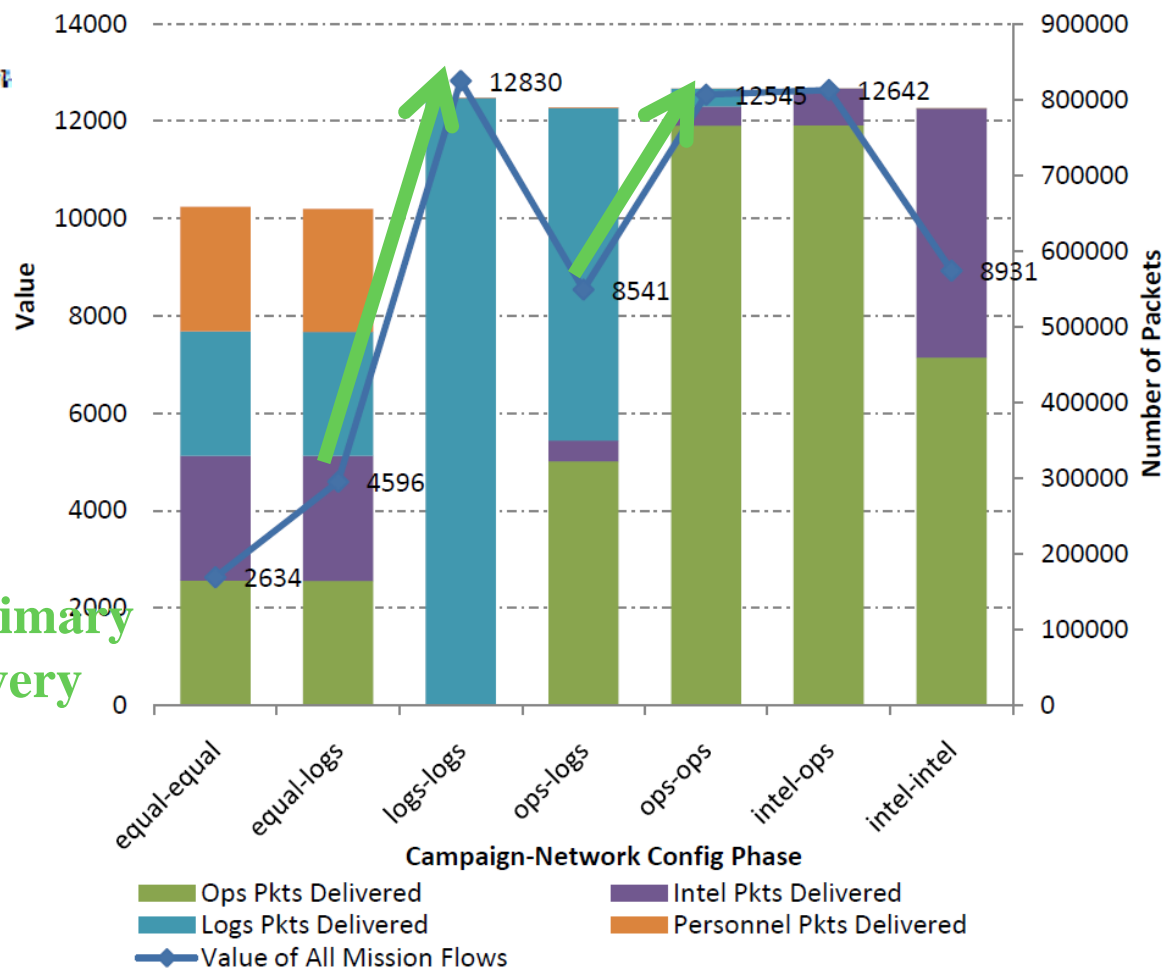
M mission areas

$$\sum_{m=1}^M$$

$$C \omega^a N_m$$

delivered value for
campaign-phase c
normalizing constant
weighted priority level
priority of mission area m
num. packets delivered
for mission area m

Increases as
prioritization permits primary
mission area packet delivery



Value



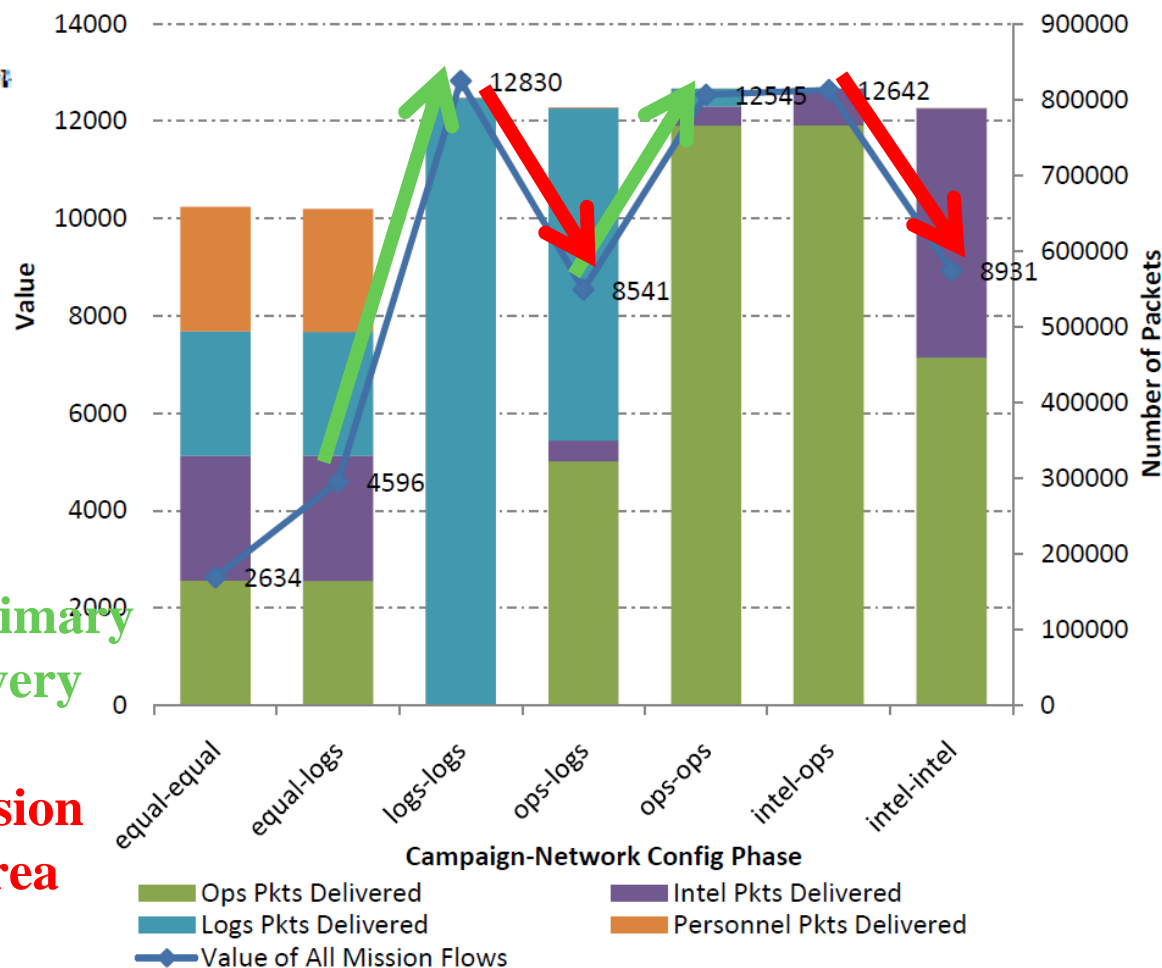
M mission areas

$$\sum_{m=1}^M$$

$$C\omega^a m N_{mv}$$

delivered value for
campaign-phase c
normalizing constant
weighted priority level
priority of mission area m
amb. packets delivered
for mission area m

increases as
uration permits primary
n area packet delivery
decreases as
g. mismatches mission
primary mission area
ry falls



Value



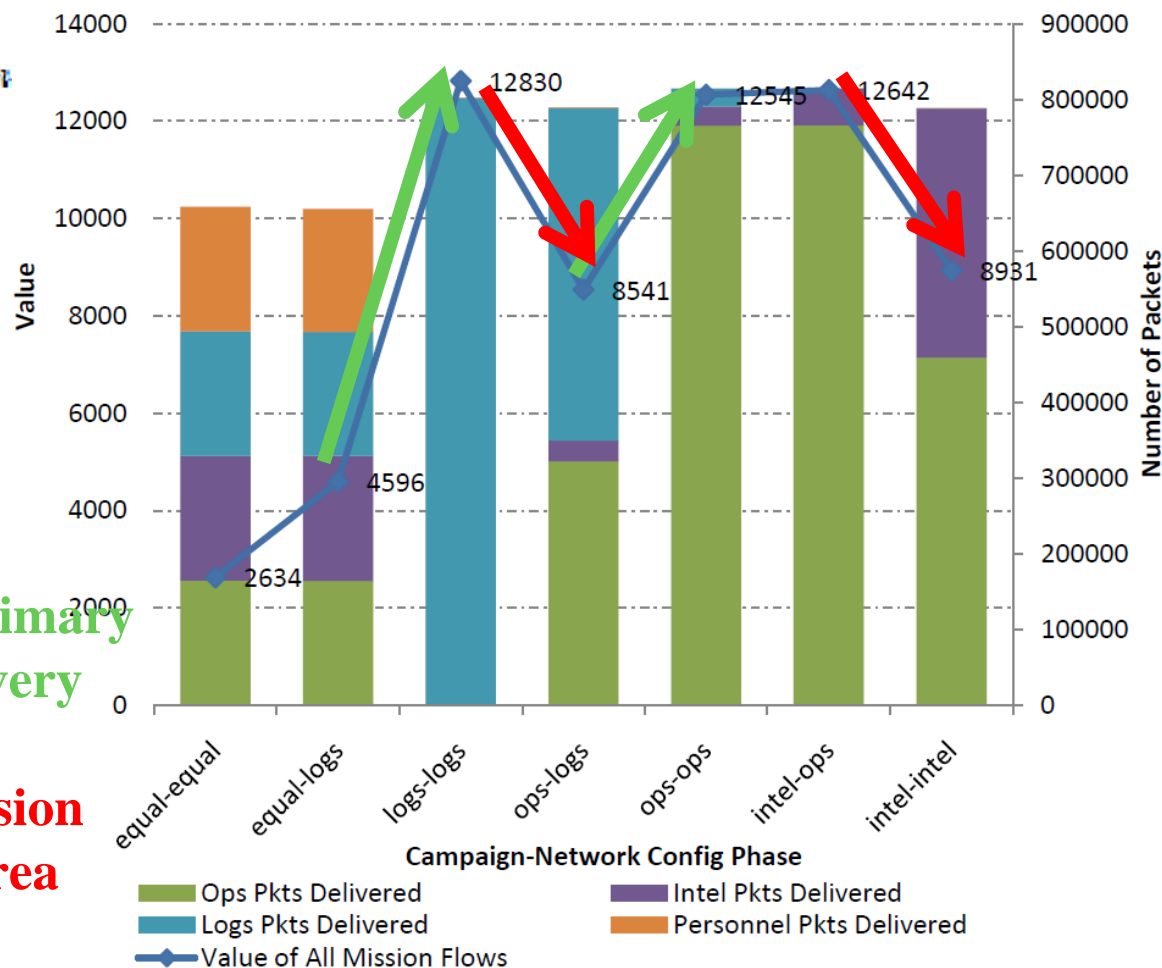
M mission areas

$$\sum_{m=1}^M$$

$$C \omega^a_m N_m$$

delivered value for
campaign-phase c
normalizing constant
weighted priority level
priority of mission area m
num. packets delivered
for mission area m

increases as
prioritization permits primary
mission area packet delivery
decreases as
e.g. mismatches mission
primary mission area
priority falls



Overall value depends on both

Next Steps



Expand to more tailored QoS methods

Develop more accurate value measure

Establish methodology to align mission and threads to QoS protocol tools

Demonstrate methodology in military use case

Improve network performance to benefit overall operations for military use case





Summary



-
- The Quality of Service (QoS) framework has promise to aid in design and operation of the System of Systems (SoS) network which must allocate scarce resources.
 - Aligning QoS configuration to mission profiles and priorities tunes network to top priorities and benefits the overall mission
 - QoS alignment must also deliver threshold performance to low priority missions to eliminate failure modes



Contact



Vinod D. Naga, Major, USAF

PhD Candidate

Air Force Institute of Technology

Dept. of Systems and Engineering Management

vinod.naga@us.af.mil

937-255-3636 x7126

*Teamwork is the ability to work together toward a common vision. The ability to
direct individual accomplishments toward organizational objectives.*