U.S. Army Research, Development and Engineering Command

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Human Decision Making Performance in Degraded Network Video Conditions (Track 2)

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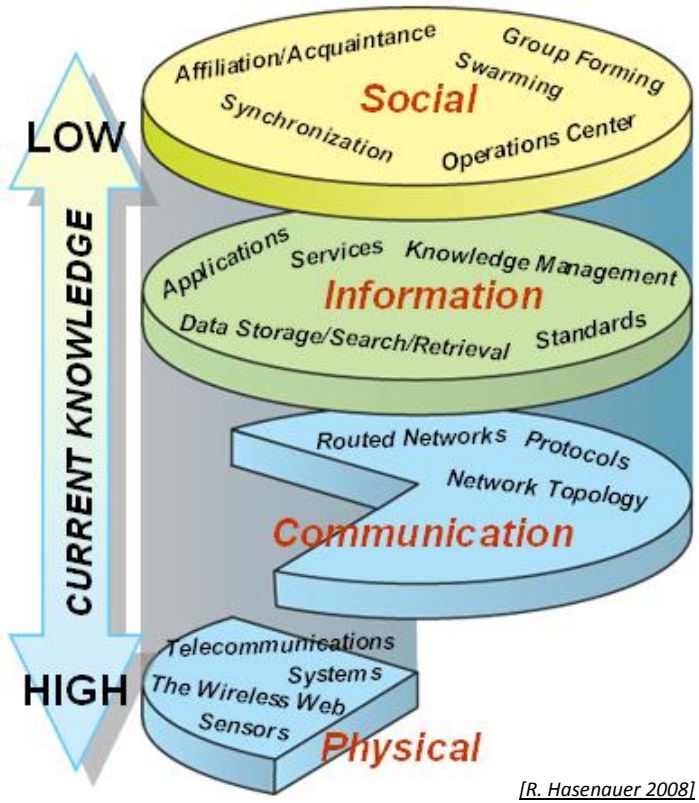
Motivation

- **Motivation:** Build tactical networks that maximize the capability/ability of the Soldier in performing mission objectives.
  - Presently, there is a lack in the understanding of the social/cognitive layers of the network science paradigm.
  - Furthermore, the interconnection of the communications, information and social/cognitive layers must be understood.



[R. Hasenauer 2008]

Challenges

- Specifically, networked devices and information services are a growing capability among the warfighter. However, several challenges arise despite advances in technology:
  - Information overload: The Soldier has access to many multimedia services (video, images, clips, http, chat, UAV feeds).
  - Transfer of information: The chain of command and the dissemination of information are potentially at odds.
  - Collaboration using the network: Soldiers need optimal and efficient capabilities to share and disseminate information.
  - Trust in network: Reliance and confidence in the battle command systems and networked devices is necessary.
- Trust as a metric to evaluate Soldier interaction with the network.

[www.spectrum.ieee.org]

Related Research Areas

- **Dimensions of Trust**: The ability of the user to gather information of its targeted environment and be able to make decisions based on these observations. The user and decision maker must possess a satisfactory amount of trust in this information.
  - Trust in Automation [Lee 04, Parasuraman 00]
  - Situational Awareness [Endsley 99]
  - Decision-making [Boyd 87]

- **Trust Experiments**: Validation of the models for human perception of video quality and dissemination of information is necessary.
  - Video perception studies [Ghinea 98, Chen, 06]
  - Collaboration Experiments [Moorman 93, Baba 99]

- **Network Optimization**: Many approaches for optimization of network performance using various metrics exist. Human trust in networks is a new metric for optimization.

Approach

Human Trust in Networks

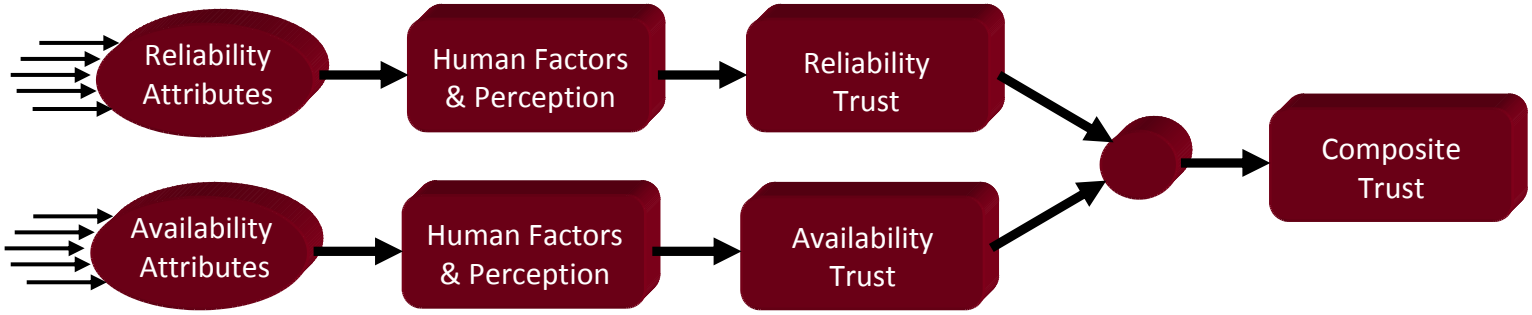
- Develop measurable models for human trust in networks (TiN)
  - Dimensions of trust : Network reliability, network availability
  - Composite trust
  - Quantifiable metrics of human trust vs. network parameters

- Experimental validation of trust models
  - Video tests for Human TiN
  - Explore emerging trends in results/analysis

- Determine approaches for network optimization
  - Routing layer: traffic rerouting, network topology optimization.
  - Application layer: information filtering, adaptive priority-based access control and delivery rate.

Human Trust in Networks Framework

General Framework of Human Trust in Networks



Availability

→ **Connectivity**: Routing protocols, servers in network, network topology, security/access control

→ **Channel Access**: MAC protocols, network traffic/congestion

→ **Data Latency:** MAC protocols, hop distances, node density

Reliability

→ **Data accuracy**: Synchronization of servers, data freshness/timeliness, signal-to-noise ratios, packet error rate

→ **Data Security:** Data integrity, authentication, validation

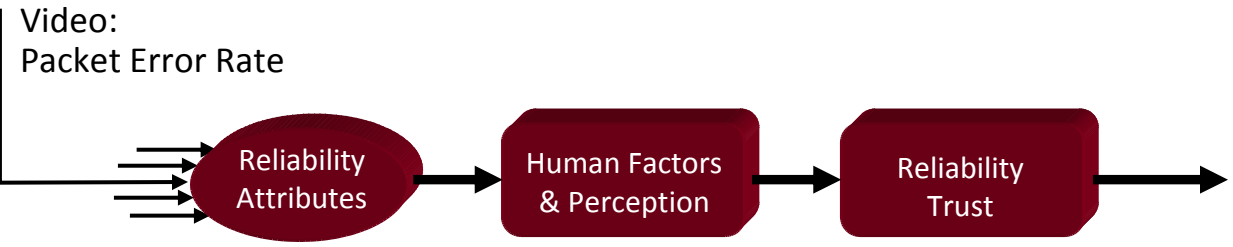
Ideas on Network Optimization

etwork Optimization on Packet Error Rate (ERR)

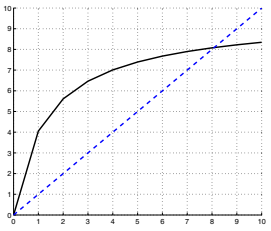
- $Trust_{REL}$(ERR) = f (ERR)
- Determine limits on ERR to provide sufficient $Trust_{REL}$ for specific scenarios.

there a threshold effect of trust in networks or other performance metrics with gard to network quality of service?

n we predict Soldier performance given network quality of service?



$Trust_{REL}$(ERR) vs. ERR



Experiments

onducted a series of experiments to study the impact of variable levels of video uality on the Soldiers ability to detect high value targets in video clips.

Soldier performance experiment was conducted to evaluate metrics as a function of acket error rate.

ther experiments were conducted three separate populations to examine parameters lating Soldier performance to video quality of service (QoS).

Emerging results

ynamics of Soldier trust and performance as a function of video QoS.

- Trust in Networks is linear with respect to video QoS.
- Difference in performance with mission objectives requiring finer information granularity.
  - Mistrust in objectives requiring less detail. Performance matched with trust at low QoS.
  - Slight overtrust with objectives requiring greater detail.

odels to predict Soldier performance given QoS in communications link.

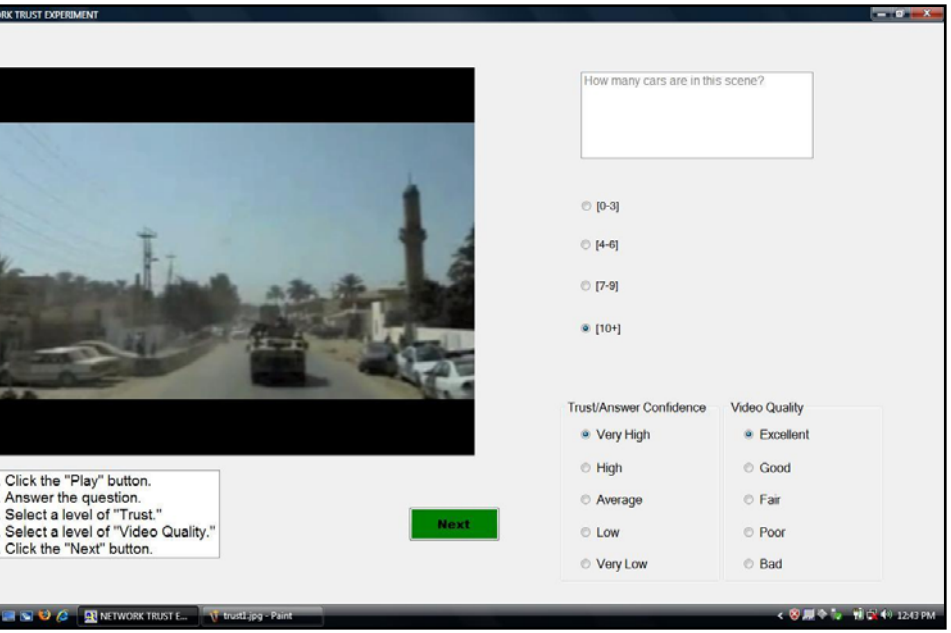
- Video Mean Opinion Score (MoS)
- Packet error rate
- Available bandwidth (BW)

Trust Experiment

ust experiment to determine Soldier performance in target detection in a networking nvironment with varying QoS.

ission requiring soldiers to extract specific information from a simulated UAV feed.

oal: determine performance behavior with respect to video MoS.



Performance Metrics

oldier performance metrics in a sub-optimal networking environment (120 uestions of 0-25% packet loss ratios)

- *Performance (PERF)*
  - Extraction of mission related information from video.
  - Correct identification of quantity or presence of particular subjects.

- *Decision Making event (DME)*
  - Identification of suspicious activity.
  - Characterization of suspicious vs. non-threatening.
  - Requires finer resolution of perception than *PERF*.

Performance Metrics *(cont'd)*

oldier performance metrics *(cont'd)*

- *Mean opinion score (MoS)* – subjective rating of video quality. [ITU-T 2009]

MoS	Quality	Impairment
5	Excellent	Imperceptible
4	Good	Perceptible but not annoying
3	Fair	Slightly annoying
2	Poor	Annoying
1	Bad	Very Annoying

- *Trust/Confidence (TC)* – trust in the accuracy of information gathered.

Trust/Confidence	Description
5	Very High
4	Good
3	Average
2	Low
1	Very Low

Experiment Mission Scenario

on Scenario

You are an intelligence analyst supporting a vehicle convoy where it is your duty to monitor a streaming video feed and detect specific threats to the convoy along the course of your route. You will be reporting this information to your superior.

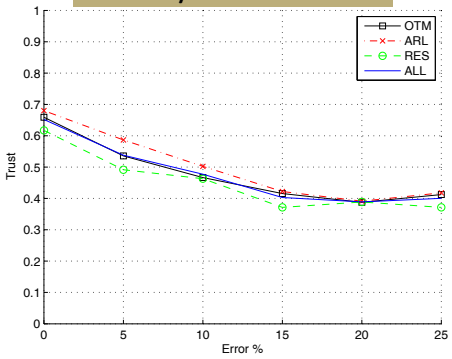
1. Mission Objectives
   - Identify the presence of the location of possible IEDs along the route.
   - Identify the number of vehicles you are able to see.
   - Identify the number of foreign nationals you are able to see.
   - Identify any observed law enforcement vehicles to your superior.
   - Report the observation of any blue pickup trucks on the route.
2. Provide your trust and confidence in the accuracy of the information that you are sending to your superior.
3. Evaluate your opinion of the quality of the video clip provided based on your ability to extract information from it.

Experimental Results

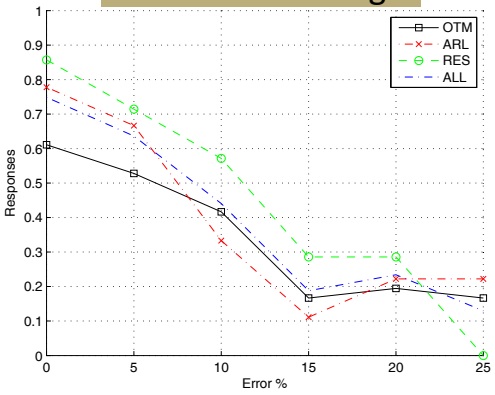
aw data

- Performance metrics vs. packet error rate (ERR)
- Trust and MoS are consistent across each testing population.

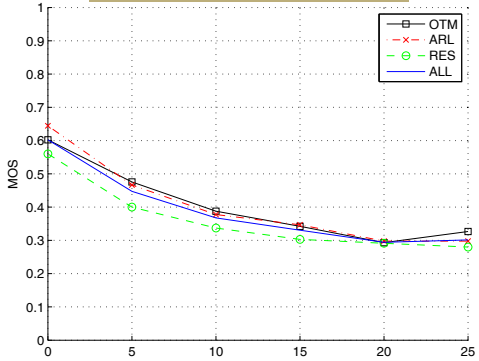
Trust/Confidence



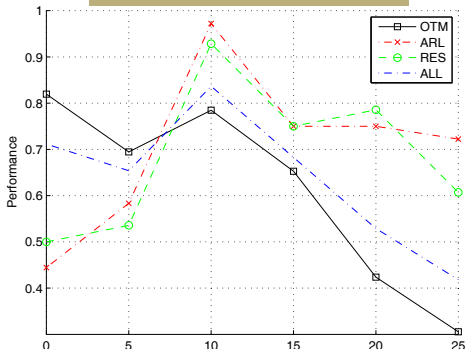
Decision-making

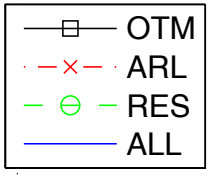


Video MOS



Performance



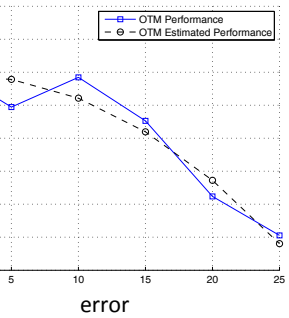


Approximation of Metrics

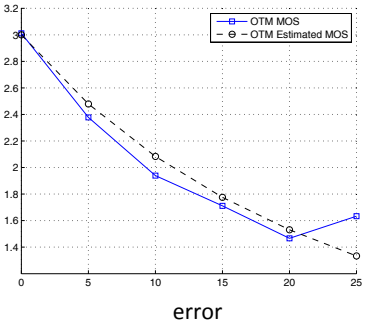
erformance metrics vs. error rate were approximated using linear regression to ccount for lack of data and assumed monotonic performance within range of error.

Metric	Function (ζ = error)	Residual (MSE)
Performance	$0.0009\,\zeta^2 + 0.0021\,\zeta + .7904$	0.0720
Decision-making	$.6/(1+0.19\zeta^2)^{1/2}$	0.1202
MoS	$0.6/(1+0.02\,\zeta)^2$	0.0720
Trust/Confidence	$.66/(1+0.3\,\zeta)^{1/4}$	0.0366

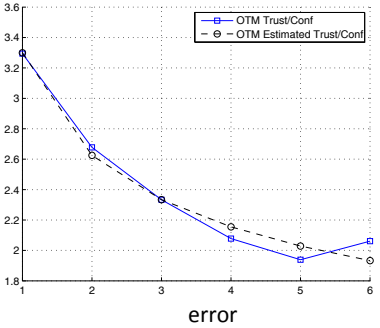
Performance



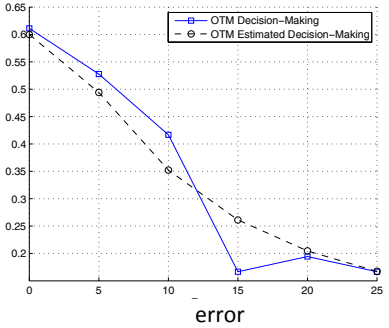
Video MoS



Trust/Confidence



Decision-making



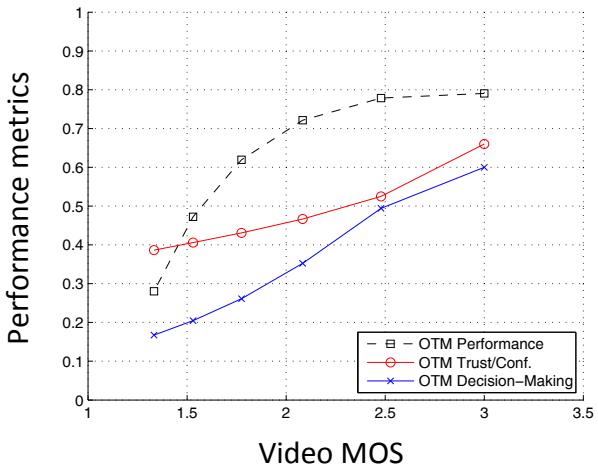
Performance vs. MOS

ehavior of Soldier performance metrics vs. packet error rate.

- Trust: linear relationship with video MoS.
- Performance: difference between simple identification of the subject and a decision based on “suspicious activity” of the subject.

s a function of MoS, abstracts reliance on codecs, and other parameters affecting deo quality.

OS is a general quality of video perception, which can be used to compare with videos om other sources or using other video QoS parameters.

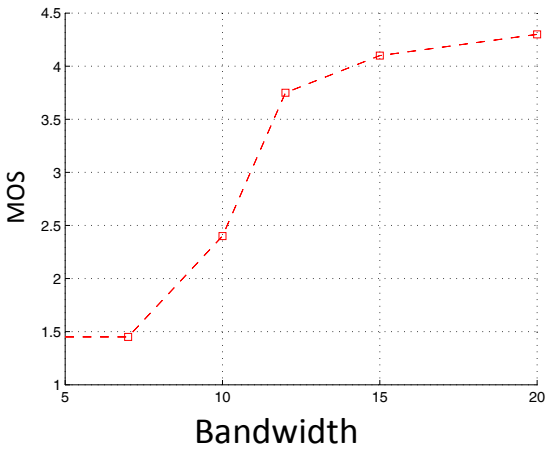


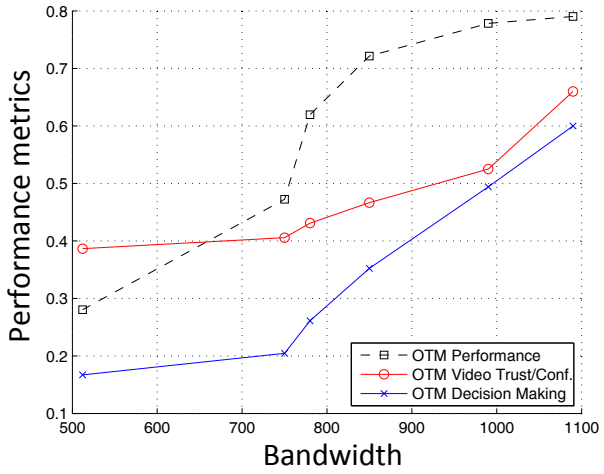
Performance vs. Bandwidth

art of C4ISROTM E09 UBC-CIS: determine the minimum bit-rate required for Soldiers
maintain acceptable levels of Soldier performance.

elationship between MoS and available bandwidth. In the Wireless Emulation
boratory, video was streamed at 1024 kbps with variable available bandwidth in link.

hreshold of performance vs. available bandwidth. The performance metrics can be
ompared vs. bandwidth.





Findings

hreshold effects with respect to video MoS, error rate, and bandwidth. Variation in erformance with objectives requiring more detail.

ith varying mission requirements links can be optimized to maximize performance nd minimizing energy usage. For mission tasks with low information requirement, trates or bandwidth can be significantly decreased, and performance will be aintained. For tasks requiring greater information, a relatively high video MoS is quired.

itial steps to characterize trust in networks and other Soldier performance metrics ith respect to communication networks.

Summary

ummary

- Conducted Soldier performance experiments with three separate populations C4ISROTM E09, US Army Research Laboratory, US Army Reserves.
- Identified trends in performance metrics as a function of network QoS.
- Results can be used to predict Soldier performance given network QoS.
- Metrics can also be used to optimize network structures or protocols to maximize Soldier performance metrics.

cknowledgements:

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- Randal Zimmerman for access to C4ISROTM E09