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Trust-based Task Assignment in Military Tactical Networks

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

[1]MoonJeong Chang, [2, 1]Jin-Hee Cho, [1]Ing-Ray Chen, [2]Kevin S. Chan, [2]Ananthram Swami

[1]Virginia Tech, Department of Computer Science, U.S.A.

[2]Army Research Laboratory, Computational and Information Sciences Directorate, U.S.A.

Outline

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- **Motivation**
- **Goal & Contributions**
- **Related Work**
- **System Model**
- **Proposed Task Assignment Protocol**
- **Numerical Results & Analysis**
- **Conclusions & Future Work**

Background

What is Trust?

- Degree of a subjective belief about the behaviors of a particular entity
- Willingness to take a risk

What is Trust Management? (Blaze06)

- A separate component of security services in networks

Measure of Trust

- Measure of potential risks
- Context-dependency
- Subjectivity
- Cognitive learning process
- System reliability

Motivation

Example Scenarios: rescuing personnel, constructing military facilities, conducting surveillance or monitoring, destroying certain targets, or managing disasters

Task Assignment

- An efficient and effective task assignment in tactical military networks is key to successful mission completion
- The best match between entities and tasks can maximize mission completion ratio

Use of Trust

- Trust-based soft security approaches can increase mission completion ratio in the presence of untrustworthy entities where traditional security services may not be practical

Goal & Contributions

Goal

- Develop a trust-based task assignment protocol that maximizes mission completion ratio while meeting an acceptable risk level using composite trust metric

$$\text{maximize } P_m^{completion}(t),$$

$$\text{given } \sum_{j \in M} r_{m,j}(t) \leq P_m^{risk}$$

Contributions

- Proposed a task assignment protocol based on the tradeoff analysis between trust and risk
- Reflected the context-dependent characteristic of trust
- Employed a composite trust metric
- Assigned multiple tasks to an entity and multiple entities to one task

Related Work

- Distributed computing systems (Jiang09)
- Wireless sensor networks (Johnson10)
- Multi-hop wireless networks (Jin12)
- Autonomous underwater vehicle networks (Kulkarni10)
- Mobile ad hoc networks (Cho11)

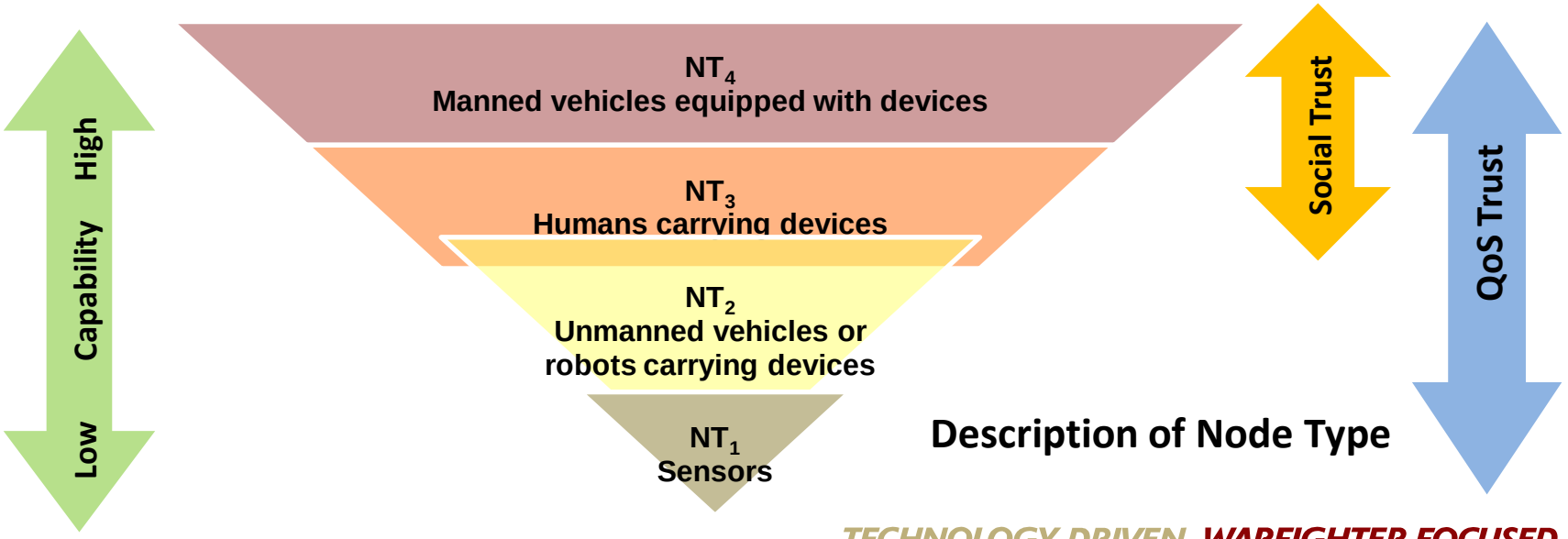
Limitations

- Mostly one node is assigned to one task;
- Analysis between trust and risk is not employed in task assignment;
- Required trust level of each task is not considered;
- Missions are not specifically modeled in terms of their characteristics

System Model:

Network Model

- Heterogeneous networks with multi-hop communications (sensors, mobile entities)
- Hierarchical structure: commander - task leaders - members
- Dynamic multiple tasks where a task arrives and ends at different times
- Heterogeneity of entities with various speed, detection error, group join/leave, and trust behaviors



System Model:

Trust Properties

	Trust property	Meaning
Social Trust	**Social Connectedness**	Number of social connections in social circle
	Reciprocity	Degree of mutual giving and receiving
QoS Trust	**Competence**	An entity's capability to serve the received request
	Integrity	Honesty of an entity in attack behaviors

Unique Task Properties

- Minimum required node type
- Minimum trust threshold for each trust property

Common Task Properties

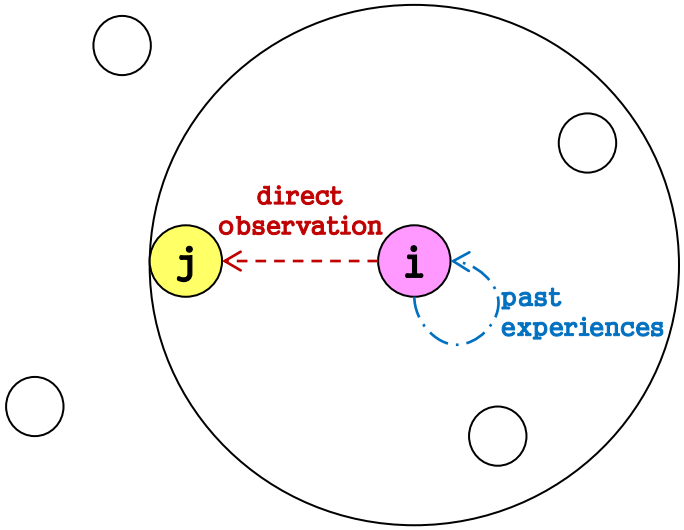
- **Importance (I_m):** How much impact is expected upon mission completion after the given task failure
- **Urgency (U_m):** How urgently the given task should be completed
- **Difficulty (D_m):** How much workload is required to execute the given task

(1- 5 levels from low to high)

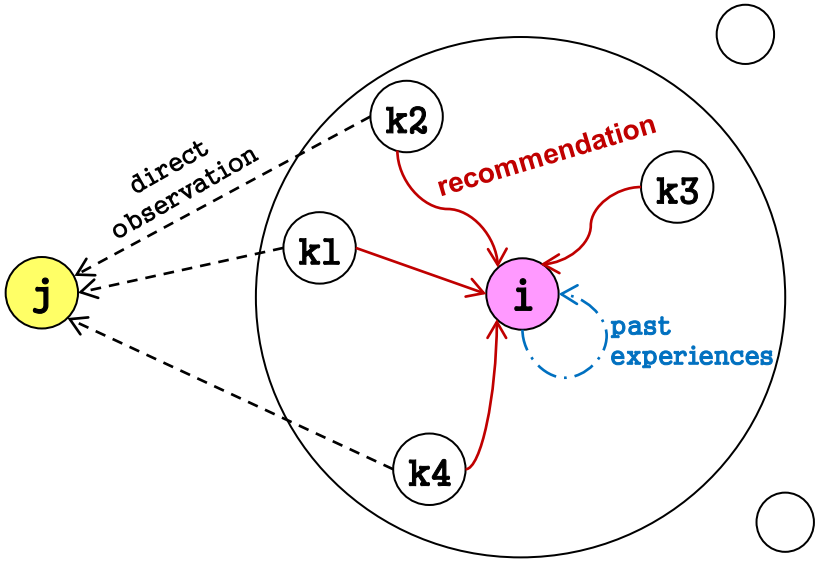
Trust Metric

$$T_{i,j}^{X}(t) = \alpha T_{i,j}^{D-X}(t) + (1-\alpha) T_{i,j}^{ID-X}(t), 0 < \alpha < 1$$

Direct Trust ($T_{i,j}^{D-X}$)



Indirect Trust ($T_{i,j}^{ID-X}$)



$$T_{i,j}^{D-X}(t) = \begin{cases} T_{i,j}^{D-X}(t), & \text{if } HD(i,j) == 1 \\ \gamma T_{i,j}^{X}(t-\Delta t), & \text{otherwise} \end{cases}$$

$$T_{i,j}^{ID-X}(t) = \begin{cases} \frac{\sum_{k \epsilon R_i^{trw}} T_{k,j}^{X}(t)}{|R_i^{trw}|}, & \text{if } |R_i^{trw}| > 0 \\ \gamma T_{i,j}^{X}(t-\Delta t), & \text{otherwise} \end{cases}$$

R_i^{trw}: set of 1-hop neighbors of node i providing trustworthy recommendations

Task Assignment (1/2)

$$s_{i,m} = v_m - p_{i,m} \text{ where } v_m = \frac{DT_m}{DT_{max}} \;\&\; p_{i,m} = \frac{w_m}{w_i}$$

Adv. of Task Spec.
Bidding
Winner Notification
Node commitment

Compute tasks' scores

Select a task with MAX $s_{i,m}$

Member

Node i

Task Leader m

Winner determination based on trust-based risk analysis

Non-member

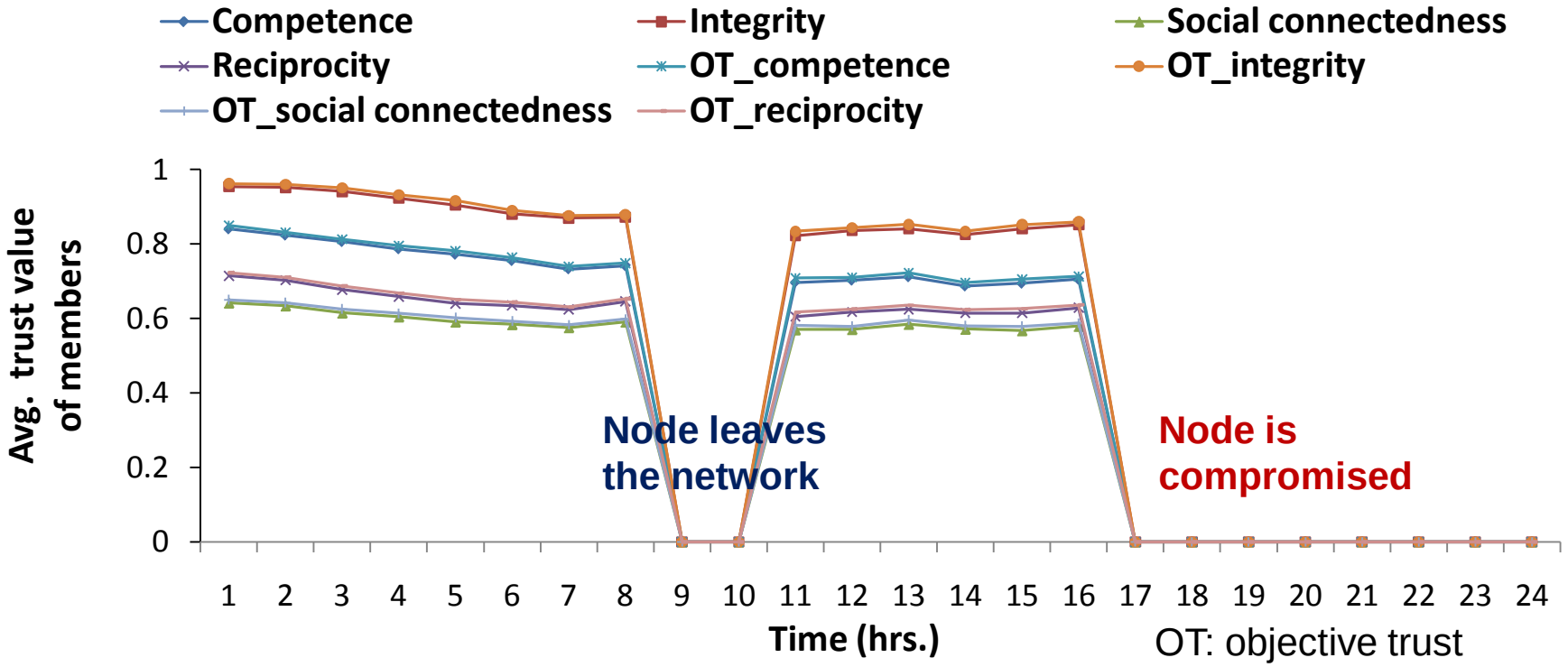
Node j

$$r^X_{m,j}(t) = e^{-\rho_1 \frac{T^X_{i(m),j}(t)}{T^{X-th}_m}} \frac{U_m}{U^{max}_m} \frac{D_m}{D^{max}_m} \qquad r_{m,j}(t) = \frac{\sum_{X \in T} r^X_{m,j}(t)}{|T|} \qquad \sum_{j \in M} r_{m,j}(t) \le P^{risk}_m$$

Dynamic Task Reassignment

- When a task leader could not recruit a sufficient number of members or finds a current member cannot continue task execution:
  1) Check if current members can execute the task with extended deadline of the task when the deadline is extensible;
  2) Look for qualified members from available members pool;
  3) Terminate the contract if either 1 or 2 does not work
  4) Label the task as incomplete (task failure)

Trust Accuracy

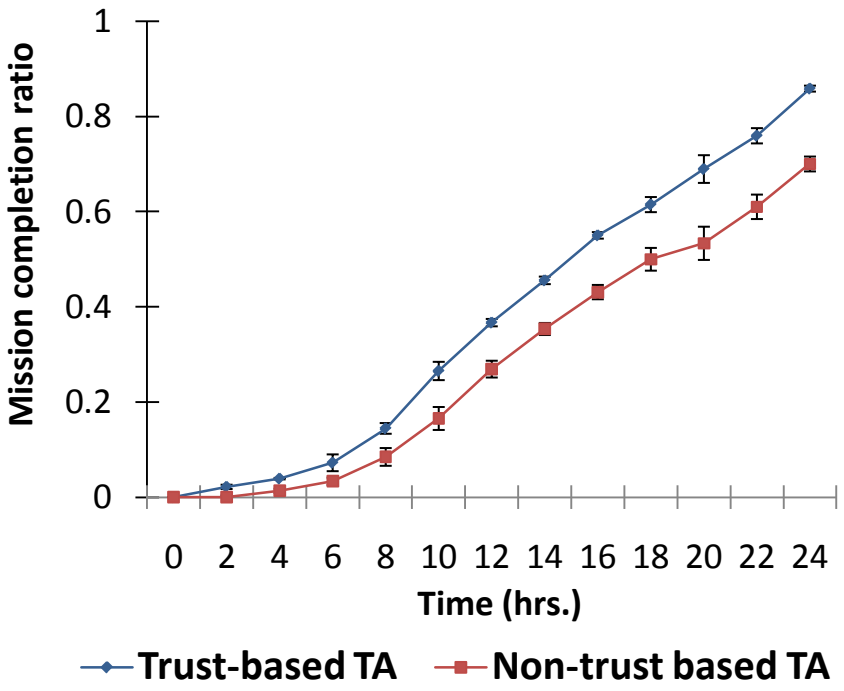


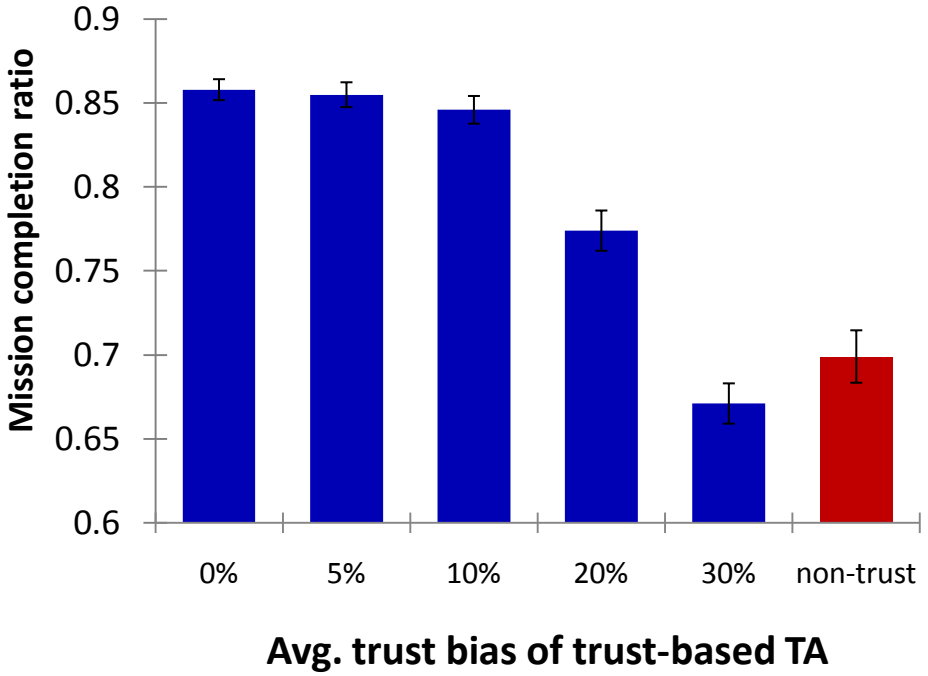
- Node Type 4 with four trust properties
- **Trust bias:** Time-averaged difference between measured trust and objective trust

$$B_{i,j} = \frac{\int_0^{MT} B_{i,j}(t)}{MT}, \text{ where } B_{i,j}(t) = \left|T_{i,j}(t) - OT_j(t)\right| / OT_j(t)$$

- Trust bias < 2% with trust decay factor γ=0.95, direct trust weight α=0.2

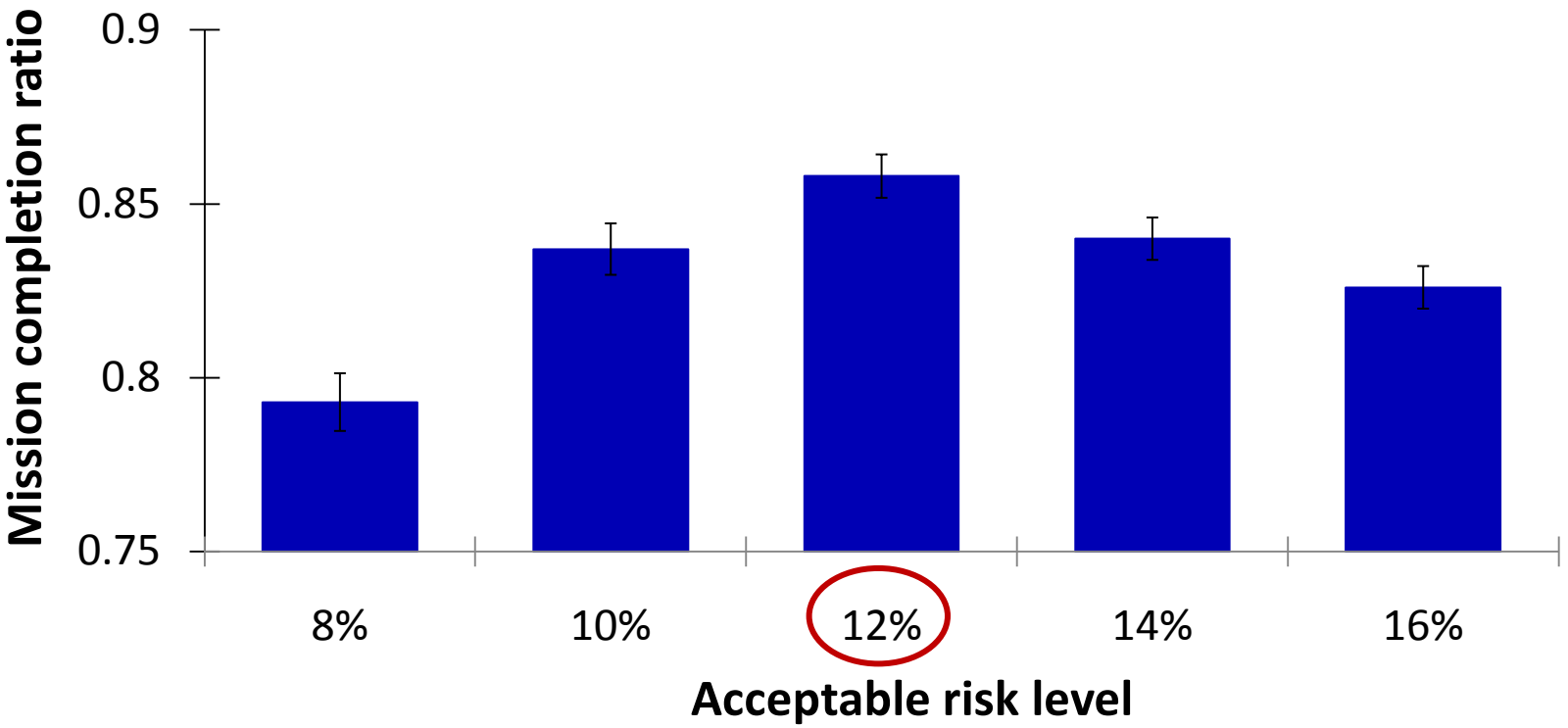
Numerical Results & Analysis: Trust Bias vs. Mission Completion





- 20 tasks & 100 nodes, 24 hours mission time
- Trust-based TA outperforms non-trust based TA
- Trust bias adversely affects mission completion ratio where inaccurate trust evaluation can mislead decision making

Numerical Results & Analysis: Optimal Acceptable Risk Level



- There exists an optimal acceptable risk level that maximizes mission completion ratio
- Composition of tasks with different importance levels may change an optimal acceptable risk level

Conclusions

- Trust bias adversely affects mission completion ratio
- The proposed trust-based task assignment outperformed non-trust based counterpart
- There exists an optimal acceptable risk level that maximizes mission completion ratio

Future work

- Examine task assignment scenarios for coalition networks
- Investigate multiple objective optimization techniques for coalition networks

Any Questions?

Contact us at:

Virginia Tech

MoonJeong Chang, Ph.D.

mjjang@vt.edu

Army Research Laboratory

Jin-Hee Cho, Ph.D.

jinhee.cho@us.army.mil