Fall 2014
SEI Research Review
Edge-Enabled Tactical Systems (EETS)

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Edge-Enabled Tactical Systems (EETS)

Investigates efficient and easily-deployable mobile solutions for teams operating in edge environments characterized by dynamic context, limited computing resources, high stress, and poor connectivity

EETS delivers impactful capabilities to stakeholders operating in mission-critical environments by providing

- Improved situational awareness and data analysis for soldiers
- Reduced cognitive load and complexity by exploiting contextual information
- Increased computing power, data access and survivability with fewer resources consumed
- Reduced operator-to-sensor ratio for groups of autonomous sensors and systems

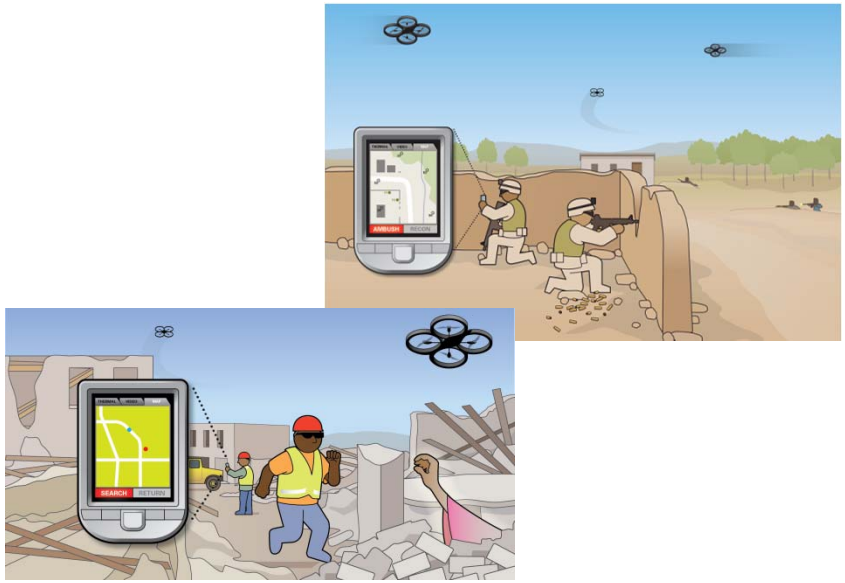
EETS Focus Areas

Group Autonomy for Mobile Systems (GAMS) *James Edmondson*	Solutions that support warfighter-directed groups of autonomous sensors and systems requiring minimal user intervention
Information Superiority to the Edge (ISE) *Jeff Boleng*	Mobile solutions that reduce cognitive load and conserve resources of individuals and groups by exploiting sensor, role/task, and event information, such that the right information, at the right time, is presented to the right soldier
Edge Analytics *Soumya Simanta*	End-to-end, real-time data analysis of static and streaming data for resource-constrained edge environments
Tactical Cloudlets Cyber-Foraging in Resource-Constrained Environments *Grace Lewis*	Cyber-foraging solutions that dynamically augment the computing resources of resource-limited mobile devices and address critical system qualities not considered by the commercial mobile ecosystem, such as survivability, resiliency, and trust

Group Autonomy for Mobile Systems (GAMS) [1]

Enabling scalable heterogeneous, collaborative autonomy

In the next decade, we expect the autonomy paradigm to shift strongly from single, often expensive autonomous platforms to large groups of collaborating, heterogeneous platforms



Challenges

- Scale
- Portability
- Effective communicate and reasoning despite connectivity issues
- More generally, how to make programming distributed algorithms with extensible platforms more accessible to the community

FY14 Research Focus: Prioritized area coverage and mission-focused group formations and behaviors as driving scenarios

Group Autonomy for Mobile Systems (GAMS) 2

Our solution approach: Design middleware and tools that enable mission-focused, scalable distributed autonomous behaviors with extensible platform support

FY14 Results

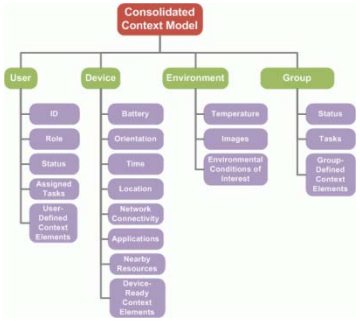
- Implementations of scalable formation flying with mission contexts (follow, encircle/swarm, force protection)
- Implementations of prioritized area coverage for smart, collaborative patrolling and search-related missions
- Demos of distributed collaboration in VREP simulations for 5-12 quadcopters and ground robots
- Open-source middleware and algorithms released to community
- Integration into CMU Drone-RK quadcopter and Platypus autonomous boat platforms
- Presentations at DARPA (CODE), AFRL C4I Workshop, and AFRL Eglin (Flexible Weapons)
- Paper published at RSN 2014 in CPS Week that outlined need for better human-autonomous group software coupling

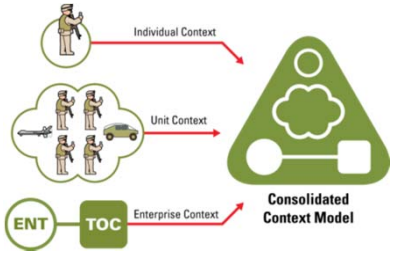
Information Superiority to the Edge [1]

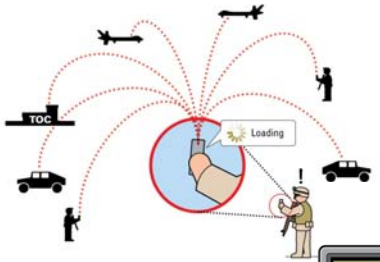
Group context aware reference architecture, middleware, data model, and prototype implementation to reduce cognitive load and conserve resources by using sensor, role/task, and event information to deliver the right information, at the right time, to the right soldier

Context Model: Expand the context model beyond time and location, resulting in broader and more complete understanding

Context Reasoning: Broader context model allows reasoning and reaction to the context of the individual, other individuals, the group, and the organization







Whole > ∑parts

FY14 Research Focus: Leveraging individual and group context to reliably deliver the right information, to the right soldier, at the right time

Resource Usage: Use of broader context allows smarter and more efficient resource allocation

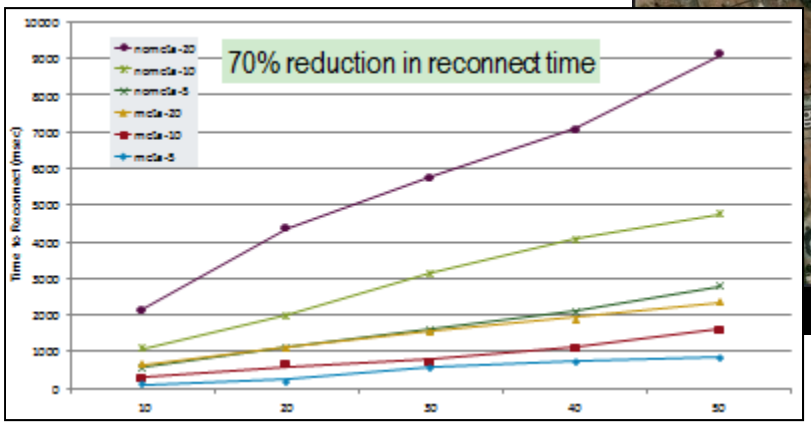
Cognitive Load: Richer context models can decrease the soldier's cognitive load required to capture, visualize and react to situational information

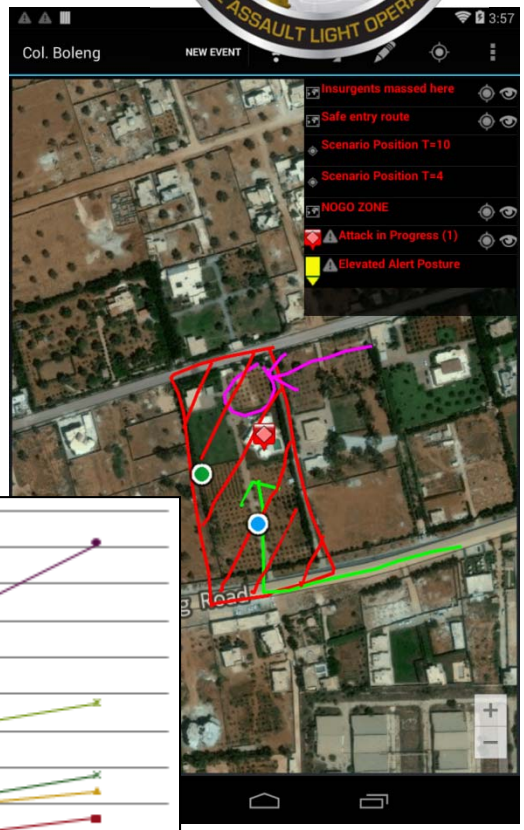
Information Superiority to the Edge 2

FY14 Results

- Group activity recognition – cooperative research with CMU HCII and 911 ABW personnel
- Integrate DTN protocols to ensure reliable data deliver in DIL environments
- Benghazi scenario prototype and demonstration
- Apply reference design and approach leading TALOS system and software architecture efforts
- Refereed paper and presentation at MilCom 2014

Paintball-based group-activity recognition event held with assistance of the 911th Airlift Wing





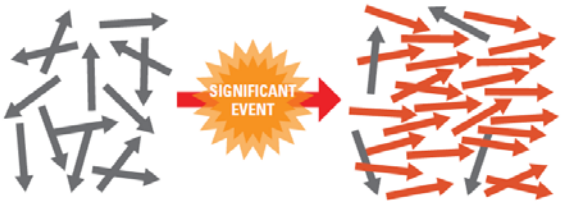
Edge Analytics 1

Enhance situational awareness of edge users in near real-time (seconds to minutes) by analyzing social media and other sensor streams to provide actionable intelligence, trends and summaries

Most analysis are batch-oriented and often done in the resource-rich "enterprise cloud" away from edge where most of the action is

Goal is to bring near-real-time analysis of data to edge environments (resource-constrained) by performing

- Timeliness-fidelity tradeoffs
- Maximizing resource utilization and elasticity
- Leveraging contextual clues from the hyper-local edge environment
- Providing more control to end users to perform on demand analysis



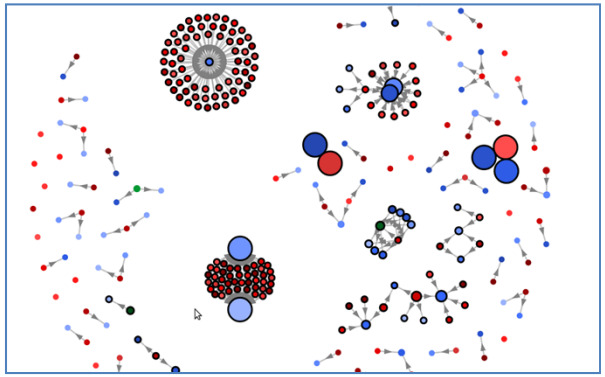
Given a local context, Significant Events are detectable as dominant trends or patterns

FY14 Research Focus: Near-real-time analysis of data in edge environments

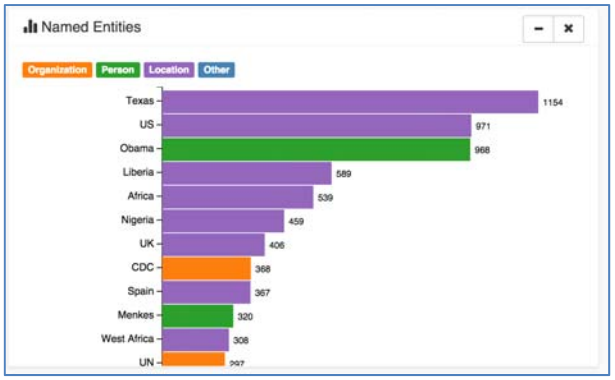
Edge Analytics 2

FY14 Results

- Event-based, asynchronous, non-blocking architecture for maximum resource utilization
- Fault tolerant and elastic to support different failure modes and edge hardware profiles
- Micro-services-based layered architecture
- Pluggable macro-analysis algorithms on textual information (e.g., named entities, sentiment, topic model, graph analysis, location inference)
- User-configurable streaming analysis pipelines and algorithms

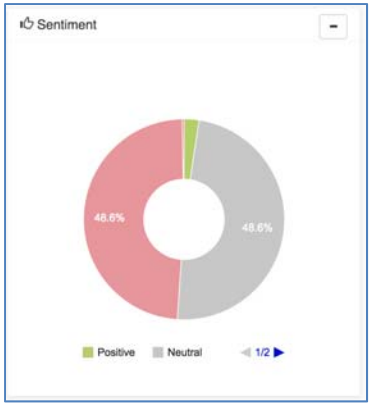


Streaming Graph Analysis (User Mentions)



Trending Named Entities

Location Inference



Sentiment Analysis

Total Tweets and Sentiment Over Time

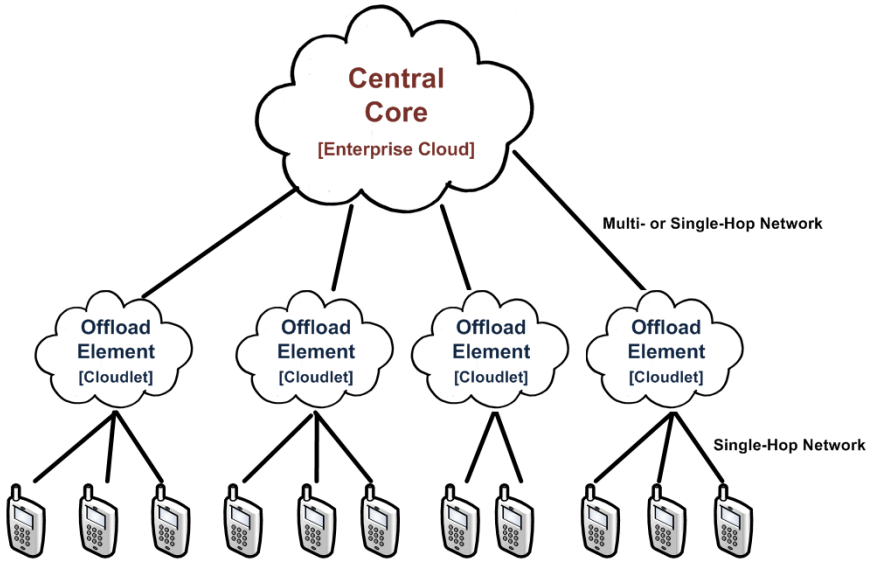
Tactical Cloudlets [1]

Cyber-Foraging in Resource-Constrained Environments

Cloud computing capabilities at the edge for computation offload, data staging, and increased survivability of mobile systems

Forward-deployed, discoverable, virtual machine (VM) cloudlets that can be hosted on vehicles or other platforms and provide

- infrastructure to offload computation
- forward data-staging for a mission
- data filtering to remove unnecessary data from streams intended for dismounted warfighters
- collection points for data heading for enterprise repositories



FY14 Research Focus: Increased survivability of tactical mobile systems

Tactical Cloudlets 2

Cyber-Foraging in Resource-Constrained Environments

FY14 Results

Edge Characteristics/Threats / Capabilities/Features	Intermittent Cloudlet-Enterprise Connectivity	Mobility	Limited battery power	Dynamic missions	Limited technical skills in the field
System Requirements	*Disconnected operations*	*Quick response time*	*Low energy consumption*	*Ease of re-deployment*	*Ease of deployment*
Pre-Provisioned Cloudlets with App Store	X	X	X	X	X
Standard Packaging of Service VMs				X	X
Optimal Cloudlet Selection	X	X			
Cloudlet Management Component				X	X
Cloudlet Handoff/Migration		X		X	

Publications

- Refereed papers at ICSE NIER, ECSA, MilCom, and MobiCase 2014
- IGI Global book chapter to be published early 2015

EETS in FY15

Establishing Trusted Identities in Disconnected Tactical Environments	Trusted identity solutions that work within the constraints of DIL environments in which there is no consistent access to third-party online trusted authorities that validate the credentials of the requester or a certificate repository
Assigning Credibility Scores to Social Media Streams in Real-Time	Algorithms that can assign a credibility score quickly (seconds) and provide a human-understandable chain of reasoning in the end user's vocabulary to evaluate the veracity of data provided by social media channels
Fusion of Social and Physical Sensor Data	Techniques to fuse data from social media with non-textual data and data from physical opportunistic sensors — Algorithms that extract sensor metadata, other contextual data about the particular sensor, and where possible, analyze non-textual and sensor data to infer context to generate new metadata
Group Autonomy for Mobile Systems (GAMS)	Transitioning to the FY15 LENS ELASTIC and FY15 LINE DART projects • ELASTIC focuses on middleware and algorithms for distributed autonomous systems that dynamically respond to user needs, resources, and mission contexts • DART focuses on the verification of distributed cyber-physical systems

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