Emergent Engineering for the Management of Complex Public Safety and Security Operations

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We introduce the concept of Self-Organizing Security (SOS) Network as a resilient architectural foundation on which the operational mechanism for deploying dynamic, short living emergency response teams of first responders and citizens capable to react quickly to emerging crisis situations can be evolved. As a short lived *meta-organization* deployed 'on the fly' from units belonging to different organizations (military forces, police, firefighters, ambulance, provincial emergency response organizations, red cross and other non-government organizations as well as civilian citizens) coming together in a collaborative endeavor to address an emerging need (an acute and developing crisis situation), an SOS Network acts as a controller that co-evolves with the crisis to regulate the emerging processes while deploying ad-hoc protective mechanisms similar to how anti-bodies are being created to fight unexpected/unanticipated intrusions.

An SOS Network equates a *network of agents* interacting intensely with each-other in generating a collective behavior that co-evolves with the environmental dynamics. Usually this imposes certain constraints on the overall network of agents – constraints encapsulated in a higher strategy, a high-level policy that supports the undertaking of concrete action plans attuned to the crisis dynamics. When responding to an unforeseen problem SOS networks exhibit a *collective behavior* much in the same manner as swarms self-organize by simple individuals interacting locally with one another and with their environment without centralized control. The individual-to-collective dynamics (how the agents create the collective behavior through the way they interact/influence each-other) in such a network depends on the particular action plan desired. Thus balancing individual protocols with the network policies to achieve a best possible collective behavior resulted in action plans deployed across the SOS Network becomes the key issue when deploying SOS Networks for emergency operations. This is realized via an intelligent communication network running an agent-based modeling and simulation capability which enables this dynamic linking of resources by weaving the normative, structural, functional, human and geographic dimensions into a holistic approach. The SOS communication network materializes the high-level policies into flexible concrete action plans that are broadcast on the fly and distributed ('compiled') to each individual top-down as local rules (individual protocols). The individual-to-collective dynamics (how the agents create the collective behavior through the way they interact/influence each-other) in such a network is seamlessly attuned to the realization of the particular action plan most suitable to addresses the situation at hand.

To achieve this, we consider an emergent engineering approach inspired from developmental biology which implements genetic-like regulation at the agent level. This enables the differentiation of agents according to their particular attributes and functions - the richer the information carried by the genotype (range of individual agent behaviours), the richer the variety of the overall phenotype (range of action plans that can emerge and be dynamically deployed). This is because a sophisticated genotype opens the door to agent *differentiation* via *positional information* – essential properties which enable programmability and evolution by combinations and re-combinations of diverse agents into modules and hierarchical constructions. These properties are essential for enabling the SOS Network with highest adaptation capability to be able to counteract unexpected and emerging threats. After reaching structural maturation (possibly on a short "deployment" time scale under high dynamics – aka when the joint teams are deployed in response to the particular malicious event), the SOS network would switch the bulk of its activity from executing the *developmental part* of the genotype (*dynamic architecting* by positioning the actors within the network such that they can perform their activity best within the team) to executing the *functional part* of the genotype (*adaptive control* achieved by acting their roles within the team as per their specified individual protocols to realize the most effective action plans).

We illustrate how our simulation modeling capability enables:

- the design of exercise scenarios involving various combinations of crises configurations to assess the joint response and based on this suggest policy changes for the organizations coming together;
- experimentation and understanding of the high-level effects (resultant collective behaviour) at the 'meta-organisational' level as they emerge from local interactions among the individual participants coming together from the various partnering organisations;
- decisions regarding changes to individual 'job protocols' assigned to individuals in the partnering organizations - based on the extent to which personnel can be educated into thinking and behaving cooperatively and collaboratively within and between mixed teams.

Recent results reflecting the extent to which our approach supports decision makers to anticipate the evolution of an emerging crisis and evaluate the effectiveness of different inter-agency configurations coming together in addressing it will be revealed together with success metrics validated against the ability of the SOS Network to:

- Cluster the most suitable organizational structures evaluating of the conflict between the individual protocols and the overall SOS network policies to determine the level of integration required to work effectively in a joint force alliance team;
- Pointing to appropriate *institutional policies* and *personnel protocols* according to which agile groupings can be deployed;
- Express how much decentralization of decision making is possible, the conditions for this to happen and the limitations of decision making at various levels;