High Bandwidth Mega-Mesh Sensor Networks
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1. Introduction:

Remote sensing technologies have long since been relegated to the implementation of airborne, or spaceborne configurations. We recognize that distributed sensors in all configurations can contribute to improved sensor performance and expanded measurement configurations. These new sensor systems require designs that can be scaled to hundreds to potentially thousands of individual sensors or sensor components. This paper describes a new sensor network design strategy and some suggested operational scenarios. We use the Chemical Biological Defense effort as a platform to discuss various approaches.

2. Background

The Chem/Bio (C/B) Defense effort requires the integration of a wide range of information bases, including data, voice and video. All these information streams must be processed, shared and stored (most are high bandwidth information streams). Currently implemented solutions are inadequate to completely fulfill the objectives of the mission of Homeland Security. Typically, communication bandwidths are too small and Quality of Service (QOS) requirements have not been implemented. The severe limitation causes service to be interrupted when many users access the system. As you might expect this occurs at a time when communication and coordination are most desperately needed—during the early stages of consequence management. In addition, current implementation schemes do not provide integrated service, interoperability, and over riding security.

Information access is vital to preemptive action, early response and consequence management, driven by natural or manmade disasters. Conventional infrastructure is vulnerable. The ability to provide connectivity on a local, metro, regional, and national scale is key to success. Data sources are varied and distributed. In crisis situations, access to critical information streams is vital to successful decision management. The immediate access to sensing imagery from spaced based platforms, large sensor networks and archived images and relational data bases will allow the decision makers to move forward with confident and timely decisions. Transparent operation does not exist and little automated C4I infrastructure exists.

3. System Requirements

To be effective C/B defense infrastructure must include a sensor network that can effectively identify and locate C/B threats on a spatial scale, to provide early warning, spatial distribution and movement. These mega-mesh sensor networks can provide early warning for critical transportation infrastructure, early indicators of C/B clouds and dispersants, and protection for large public places. Additionally, remote sensing imagery will be critical to provide baseline measurements for comparison, change detection and mapping. One critical component must include rapid asset positioning and information retrieval.

Mega-Mesh sensor networks require special design to support effective communication protocols. There will be a requirement for sensor-to-sensor communication, ad-hoc/self organizing network, multiple individual communication network structures, wireless base stations, remotely charging techniques, etc. All of these approaches dictate unique network architecture that eventually interface to special communication infrastructure and/or legacy networks.

Mega-Mesh sensor networks will evolve toward a fully nomadic yet fully interconnected deployment. The C/B Mega-Mesh network would be capable of integrating sensor inputs, enabling in-situ decision processing, automatically configuring deployed sensor infrastructure, directly interfacing optical and wireless sensor technologies to the C4I infrastructure, and supporting ad-hoc sensor network formation and reconfiguration. The proposed concept comprises the design of resilient ad-hoc networks, realistic simulation at the software and hardware levels, and evaluation of performance with existing and/or proposed C/B sensor packages. The proposed concepts will provide the technical capability for the development of Mega-Mesh networks capable of large infrastructure C/B detection, characterization, and deployment.

Chem/Bio detection requirements dictate multilevel protection in the sensor network. Use of high sensitivity, high fidelity, multi parameter instrumentation (currently used and required as part of the complete network) limits the ability to develop cost effective deployment schemes that can provide spatial discrimination. Networks
constructed of hundreds or potentially thousands of inexpensive sensors (termed Mega-Sensor Networks) would provide spatial detection capability at reduced sensitivity or discrimination capability. A combination of both sensor types is required to provide adequate protection against C/B attack.

4. Summary

The issues are (1) design of efficient sensor networks, (2) self organizing, (3) scaling to hundreds or thousands of sensors, (4) development of Quality of Service Protocols, (5) interface to legacy infrastructure, (6) connectivity and power issues for the sensors, and (7) deployment strategies.

We describe the operating design and performance characteristics of a sensor deployment that integrates hundreds of wireless sensor to a C4I infrastructure to predict spatial distributed of the measured parameter. In this specific case a measurement of distributed atmospheric turbidity in a near surface environment is described. System design and network characteristics will be discussed.