Information Sharing and Decision Support for C(I)IP

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1 Introduction

Interdependencies among the elements of national and transnational critical infrastru
tures necessitate coordination and cooperation among infrastructure operators as well
with government [TH03]. The scope of information sharing is typically limited by co
fidentiality requirements since infrastructure operators may both be in competition w
one another and have concerns over commercial intelligence and excessive disclosure
internal procedures and processes to the general public. This, however, can change rapi
when transitioning from regular operations to crises or large-scale disruptions.

Such transitions from regular operations to damage or crisis control may occur very rapi
and frequently must be dealt with quickly to avoid further cascading effects and damag
Controls on information exchange that are effective and prudent during normal operat
may no longer be appropriate in such environments, and normal communication chann
may either become unavailable or prove to have bandwidth and latency that is too low
the amount of data that needs to be exchanged (e.g. in case of communication that is n
mally handled by voice or facsimile during regular operation). While exercises (e.g.
LÜKEX exercises at the national level in Germany) can assist in establishing and ex
cising communication channels for use in crisis environments, the ad-hoc nature of th
communication paths clearly limit their overall utility.

Information sharing mechanisms for critical infrastructure environments should theref
provide benefits to the efficiency and efficacy of normal operations of critical infrastru
tures to provide an incentive to use the information and information sharing platform re
larly and extensively and permit its efficient use during crises and major events. Impro
familiarity of operators with the platform as well as with the internetworking capab
ties can then provide valuable increments in the speed and efficacy of handling criti
situations while improving the cost-effectiveness of regular operations through increa
transparency of infrastructure assets, procedures, and operations.

Moreover, the precautionary integration of data sets and streams that are potentially
interest to a decision maker during a crisis event could be justified only with difficult
no tangible benefit can be derived for the infrastructure operator during regular operati

Even if the overall cost of a large-scale cascading infrastructure failure and probability
such an event would indicate that such a course of action would be beneficial on a glo
scale, it should be noted that such considerations are not compelling for individual infr
tructure operators as the total (or even fractional) cost of such a disruption is not bor
fully by the infrastructure operator. It is therefore of vital interest to provide an additio
incentive to infrastructure operators in the form of efficiency gains during regular operati
for the adoption of information sharing and decision support systems.

Information sharing and decision support systems integrating heterogeneous data sourc
are of interest not only for use among multiple infrastructure operators but also with
individual infrastructure operator organizations since data repositories and sensor data
both hetereogeneous and subject to frequent change over time and may therefore requ
integration measures even within a single unified organization. This is in part owed to
considerable costs associated with recording e.g. geospatially referenced data that must
retained for long periods of time during which measurement and record-keeping proc
dures may change significantly.

2 A Standards-Based Information Sharing Framework

Information sharing for C(I)IP can be performed efficiently if two core requirements
met. One is that the data formats used to represent the various types of streams and d
items must be capable of reflection, i.e. of incorporating the requisite ontological inf
mation to ensure long-term stability as well as the ability to exchange data sets amo
(sub-)organizations with disjoint operational semantics. This ensures that the semant
of data streams can be retained even if changes or translations need to occur. The seco
closely related requirement is the use of a common underlying syntactical format for
representation and classification of varying media types that are constituting the total
erational situation. Moreover, individual data items need to be verifiable in their integr
and authenticity both at the time of use and at a later date, e.g. during the course of
audit or other review process.

Given that infrastructure operators will frequently already have command and control sy
tems in place, it is also highly desirable to create an information sharing and decisi
support infrastructure that is modular and can be integrated into such existing systems
a loose coupling.

These requirements (as well as additional requirements described in [Wol04]) can be r
by using techniques developed within the W3C Semantic Web project. Web services w
well-defined interfaces for data sources that can be self-describing provide fine-grair
input data streams that can be modified and extended individually as well as being su
ject to precise security controls. Moreover, the syntax and semantics of the individ
data streams and sources can be described within the W3C resource definition fran
work (RDF) [BR05, Wol04], providing the ability to dynamically transform and transl
metrics and error probabilities between sensors and data sources. Provided that a co
mand and control system is equipped with the necessary transformation and filtering ru

described within the RDF framework, it can integrate new sources into the informati
system without requiring extensive adjustments to the overall system architecture.

While this ability to dynamically configure multiple source information sharing is an i
portant improvement over existing information systems for C(I)IP in its own right for b
internal use within a single infrastructure operator and, more importantly, also among m
tiple infrastructure operators even on an ad-hoc basis when e.g. necessitated by a ma
crisis requiring large-scale cooperation among infrastructure operators, another prope
of an RDF-based model for information structuring and exchange is that it is possible
use the embedded semantics and formalized ontology as the basis for automated reasoni
over the data contained within the individual sources and data streams.

Provided that all data sources are rigorously annotated with the necessary ontological d
the semi-rigorous model-theoretic definition of the formal semantics of RDF e.g. allo
the formulation of queries regarding semantically related information sources (e.g. of s
sors related to a specific component of a power plant or within a specific geolocation)
the identification of extraordinary and correlated events. This ontological representat
[Sow00] is also implementable using W3C Web Ontology Language (OWL), which
be considered a syntactical and semantic extension of RDF and defines descriptions
classes, properties and their instances and, more importantly, semantic entailments wh
can be used for reasoning within the ontological model. To ensure that entailments can
computed and computed efficiently, the OWL language must be constrained in its expr
siveness; for the purposes of the modeling described in this paper a well-defined sub
of OWL called OWL description logic provides such a constraint. Description logics
somewhat limited in their expressiveness [BCM$^+$03] but do permit the use of a determ
istic computational model.

Moreover, the RDF/OWL framework, in conjunction with a graph-based dependency m
can also form the foundation of a provably secure and fine-grained model of security c
trols that is equally applicable to individual and internetworked infrastructure operat
[Wol04]. This provides the necessary assurance and flexibility to dynamically interl
information sources.

3 Geospatial Data-Based Decision Support for C(I)IP

Information sharing, particularly when large numbers of data sources must be integra
and correlated, is faced with two key challenges. First, any information sharing and
cision support system must take into account the cognitive limitations of decision m
ers in the number of events that can be recognized and integrated in the decision m
ers situational picture and awareness. It must therefore provide the ability to aggreg
and prioritize information (as described in the preceding system, this can at least be p
tially automated) before presentation to the decision maker. Moreover, given the sa
source information, an information and decision support system must provide indivi
alized reprentations to reflect differing cognitive capacities, mental models, and differ
priorities and objectives among multiple (also distributed) decision makers.

The second challenge is to provide a shared cognitive platform for the representation
the various information sources. A multimodal visual presentation mechanism using b
topological and topographical information can provide situational awareness by present
objects, dependencies, and interrelations within a common situational view that also inc
porates background information from various sources. The presentation of the collec
data on infrastructure elements and environmental conditions as well as the integrat
into relevant information that is immediately required by decision makers can occur i
number of different views depending on the task at hand.

Since a significant number of infrastructure elements have network characteristics (i.e.
pend on edges connecting individual vertices, as in the case of telecommunication or pow
transmission lines), a topological view provides key insights in an abstract format wh
permits dependencies to be identified and analyzed. However, a purely topological vi
may omit highly significant data points that can be critically important to know for de
sion makers. Particularly when multiple infrastructure elements or external threats such
weather events are to be considered, a topological view does not provide the appropri
context to judge such influences. Moreover, while some mutual and transitive depend
cies can be identified automatically, these may dependencies and interactions may not
be known in advance and can only be derived intuitively given an appropriate presentat
of the data.

Geographical information systems [LGMR99] can provide this contextualization as w
as a foundation for integrating the varied types of information that must be aggrega
and selectively displayed for decision makers. A particular challenge for the presentat
mechanism is tightly coupled with the usage patterns likely to be found in all applicat
areas from planning to emergency management, namely that the information presented
likely to be shared visually (e.g. in the same situation room or in the field) with individu
for which the security controls have no information.

4 Related Work

The modeling and simulation of critical infrastructures has gained significant attention
recent years [Ami00, DPS02, Rin04], but has been mainly constrained to the assumpt
that sensors and information sources were defined a priori and homogeneous in natu
The types of analysis imposed by the analytical models ranged in their in the level
detail from simple dependency analyses to elaborate models containing continuous ph
ical submodels (e.g. for oil and gas pipelines or electrical grid systems) [NNC+05]
well as behavioral models.Among the earliest and most widespread is the application
a control systems approach [SKDG99] including hybrid mechanisms [JM04]. Parti
larly for behavioral modeling, agent-based systems have also been investigated in de
[Nor00, TNMP03].

The use of computer-supported cooperative working environments (CSCW) and gro
support systems (GSS) has been investigated extensively, primarily from a human-comp
interface perspective [Ram99, SJY01, AvD05].

5 Conclusions

In this paper we have argued the need for the establishment of a common technical a
organizational framework for the representation and controlled exchange of georeferenc
data among critical infrastructure operators and other interested parties, including natio
and regional governments and governmental agencies.

Using a standards-based platform for information sharing and fine-grained and proval
secure access controls provides the ability to cross-link infrastructure operators and g
graphically dispersed organizational units within individual infrastructure operator or
nizations as needed using a common cognitive model that can support both topographi
and topological visualization mechanisms.

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