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DEVISING A WEB-BASED ONTOLOGY FOR EMERGING WIRELESS SYSTEMS: THE CASE OF EMERGENCY MANAGEMENT SYSTEMS

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Abstract

Ontologies provide an overarching framework and vocabulary to describing system components and relationships. As such, they represent a means to devise, analyze and compare information systems. This research is investigating the development of a software-based ontology within the context of a rural wireless emergency management (EMS) system. Wireless EMS can be considered as an emergent system, as it has developed in response to the unprecedented growth of wireless as a means to communicate in emergency situations (e.g., mobiles now account for over 50% of emergency 911 calls). The research objective of this case study is to investigate the utility of a new ontology-based framework for wireless emergency response in rural Minnesota. The ontology is developed by integrating concepts and findings from in-depth field reviews in Minnesota into an ontological software originating out of bioinformatics. This software, Protégé 2000, is an open source ontological software system developed by Stanford University's Medical Informatics group. Using Protégé 2000, this project has developed a wireless EMS ontological framework populated by the real data gathered within the case study. This EMS framework distinguishes between classes of systems, instances within the classes, and the relationships among classes and instances. The next step in the research program is to apply the ontological framework to a second case study in rural Minnesota. This case study will allow for use of the framework as a visually-oriented knowledgebase, including web-based performance information. It is expected that such an Internet use of ontology-based visually-oriented performance data will assist researchers and program managers with identifying basic problems in terms of technical and non-technical rural EMS performance issues, as well as advance the general field of ontology-driven IS systems.

Keywords: Web-based otology development, emergent systems, wireless emergency management, rural Mayday, Enhanced 911

Introduction

Ontologies are of increasing interest to Information Science researchers and professionals (McGinnius, 2002). This interest stems from both their conceptual use of organizing information and their practical use in communicating about system characteristics (Juriska et al. 1999). Many ontological frameworks have already been developed by academic disciplines such as computer science and bio-informatics and applied to broad variety of businesses from high-tech industries to agricultural sectors (Noy et al. 2000). Within the field of IS, attention to "ontology driven information systems" is now on the rise because the concept of ontology promises a framework for communicating among architectures and domain areas.

In general, ontology refers to explicit specification of a conceptualization. Ontology development and use of supporting tools offer an opportunity to utilize a unifying framework that embodies objects and concepts, their definitions and relationships between them (Gruber 1993). Ontologies also make representative content available for knowledge sharing-a set of "consistent vocabularies and world representations necessary for clear communication within knowledge domains" (Leroy et al. 1999). Three main uses of ontology are for communication, for computational inference and for reuse (and organization) of knowledge (Gruninger and Lee, 2002).

This study is motivated by all three uses of ontology in the course of developing a software-based ontology-driven system to tackle the complexity of emerging wireless EMS. This research takes an inductive approach to ontology system development and applies it within a framework to clarify the domain's (wireless EMS) structure of knowledge. Moreover, it aims to contribute to the use of ontologies for determining and achieving high-quality data relative to system attributes and functioning. As Wand and Wang (1996) note, "to design information systems that deliver high-quality data, the notion of data quality must be understood. An ontologically based approach to defining data may be the ticket of success in real world systems." (Wand and Wang, 1996, p.88).

Emergency Management Systems

Wireless EMS in rural areas is the specific domain of our research. There is increasing pressure to use this emerging system (EMS Wireless Mayday) for medical emergencies, yet little is known about its functionality and performance dimensions. Conditions driving the problem include rapid growth of cellular phone use for mayday, strong policy interest in "first-responder" Mayday as a consequence of September 11, and policy regulations toward enhanced 911 (E-911) capabilities throughout the US. Statistics about system growth document this rise: Wireless 911 calls have grown from 22,000 per day in 1991 to 155,000 per day in 2001, and in many regions wireless calls represent the major form of emergency notification. (CTIA, 2002). In short, the mobile (cellular) phone has become the de facto safety lifeline, particularly for mobile travelers and especially in rural areas.

While there are several policy, market, and technological pressures leading to emergency management system growth, the full system is quite dynamic and still unfolding—hence, it is not very well understood. Drawing upon the findings from preliminary fieldwork, the authors have identified technical, organizational, and policy dimensions to wireless EMS systems. In this paper, this framework is advanced by specifying its details within the parameters of a web-based ontology. The process of creating this ontology is the subject of this paper.

Method

Research Approach

The ontology development methodology used falls into the category of *Inductive Approach* (Holsapple and Joshi, 2002). Development techniques ascribing to this approach require observing, examining, and analyzing a specific case in the domain in a non-static fashion. As mentioned by Holsapple and Joshi (2002, p. 44) "The resulting ontological characterization for a specific case is applied to other cases in the same domain". The *Inductive approach* to ontology design fits perfectly to our purpose of using, developing, and reusing the ontology in spiral fashion as to validate the conceptual framework.

This inductive approach is particularly appropriate because of the emergent nature of wireless EMS services—that is, the system is growing rapidly and very dynamically due to a number of market, and technology considerations. As advanced by Markus, Majchrzak, and Gasser (2002) such a context lends itself to a design theory approach whereby the system is captured at a point in time, whilst its eventual functioning may be undetermined.

Knowing this, it is our intention to focus on wireless emergency response management implementation with particular attention to "on the ground" technical and "non-technical" dimensions. In this case, the "on the ground dimension" was the context of rural deployment in Minnesota. Minnesota has a distinctive approach on delivering emergency services to rural areas as compared to other states. The wireless EMS is not limited to E-911 infrastructure where Public Service Answering Points (PSAPs) play the key role. Nine centers were established called TOCCs (Transportation Operation Communications Center), in different counties to aid emergency response agencies and incident management dispatches. Our fieldwork involved in-depth field interviews and site visits in Minnesota while concurrently developing subsequent versions of the ontology. The findings and concepts from these field reviews were then integrated into the ontological software that includes its knowledgebase populated with collected data.

EMS Ontology Development Method

The ontological-development task is to analyze this framework and the cases it was derived from using a platform-independent ontological software product. This process is summarized in Figure 1 and includes the following steps:

1) Initial Interviews and Field Visits (case study 1 input to develop socio-technical framework for EMS)
2) Develop the first version of the ontology.
3) Apply Ontology to second case study, including gather performance metrics and analyzing data using project software/knowledge base.
4) Develop new versions of the ontology by revising the data collected.
5) Publish ontological knowledgebase in the web for online collaboration with other EMS/E-911 efforts.

This analysis also addresses how to measure and communicate EMS performance by using an ontology and knowledgebase designed for collaborative analysis and communication. Thus the availability of solid wireless EMS measurements and metrics for measuring performance is important. In order to define and classify quantitative performance metrics previous EMS data collected by TOCCs and EMS agencies will be used. Examining such data could tell us:

- How have response times changed over time?
- Where are the weak link(s) in the process?
- How will TOCCs deal with new technology?
- How scalable is the system in terms of capacity to manage rapid growth?
- What are the appropriate performance metrics and how can these be captured in an ontological framework?

These steps aim to execute a preliminary round of knowledge acquisition effort for the domain of EMS in rural areas. At the end of the ontology and knowledgebase development process our goal is to create the domain specific knowledge for rural Minnesota's EMS/E-911. It can then be shared with other EMS/E-911 initiatives in other states, which should further evolve and enrich the ontology. To accomplish this research objective, Protégé 2000 was adopted as a tool for devising the EMS ontology.

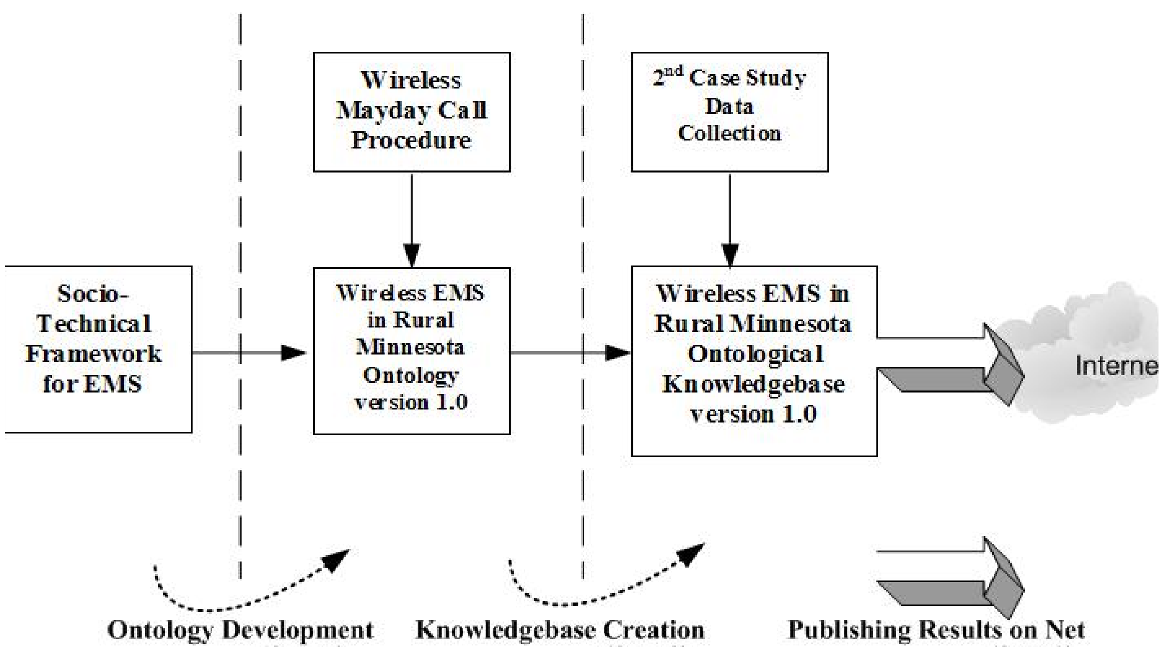

Figure 1. Research Approach to Wireless EMS and Ontology

Adoption of Protégé 2000

The EMS ontology was developed using Protégé knowledge acquisition software. Protégé 2000 is developed by Stanford University's Medical Informatics Group as an ontology editor and knowledgebase editor (Grosso, et al. 1999). It is a java-based, platform-independent tool for developing ontologies and knowledgebases. Protégé 2000 fit our objectives for the following reasons:

- It is platform independent.
- It has a user friendly GUI.
- Simple implementation (almost no code writing is required).
- Ontologies developed by Protégé 2000 can be published in the Web.
- Instances for classes can be stored and retrieved easily.
- It is scalable.
- Adequate technical support is provided online.
- Plug-ins are available for a variety of purposes.
- It has been proven in a research environment for several years.
- The software is under continuous development and improvement.

In short, Protégé 2000 is generally well equipped to portray and organize the ontology for EMS services in a visually oriented and structured manner. Moreover, web publishing of the outcome in the form of an ontology and knowledgebase will increase the accessibility to the domain knowledge. Protégé capabilities in this regard would allow researchers to browse EMS ontologies and knowledge bases rather than scanning hundreds of pages of technical consultancy papers and documents to quickly find and navigate domain specific knowledge.

Findings to Date

To date, we have completed the case study for use in devising the ontology, developed a version 1.0 of the EMS ontology using Protégé 2000, and are currently in the process of organizing the second case study to apply the ontology and create a knowledgebase. The findings below are based on these results to date.

A Socio-Technical Framework for EMS

Figure 2 provides a high-level overview of EMS systems in rural Minnesota as a result of field visits and interviews. The framework helps to define the EMS system along several key strata: organizations, technology, and policy. A brief summary of each layer of the framework follows.

- Organizations - The framework illustrates some of the public and private organizations involved in the Minnesota EMS and the general interorganizational relationships between these organizations.
- Technology – The top layer of the framework illustrates some of the essential networks and communications technologies used by Minnesota EMS organizations to carry out their individual and interorganizational functions.
- Policy – In order for EMS interorganizational relationships (ie partnerships, joint ventures, etc…) to succeed, policies need to be developed that facilitate the interorganizational use of new and existing communications technologies. The overarching EMS technology-related policies currently under development in the state are illustrated (e911, 800 Mhz radio).

Wireless Emergency Call Routing

While this general system architecture is useful in defining system strata, for the purposes of developing the ontology, it was necessary to translate the overall EMS system architectures into a process that traces the information flows across the EMS system. Figure 3 below shows the wireless mayday call routing procedure in rural Minnesota designed for use in the preliminary design phase of the ontology. Essentially, the information flow is charted, from the originating emergency call, to the e-911 center (PSAP) and out to various emergency service providers. This procedure is going to be explained thoroughly in following pages.

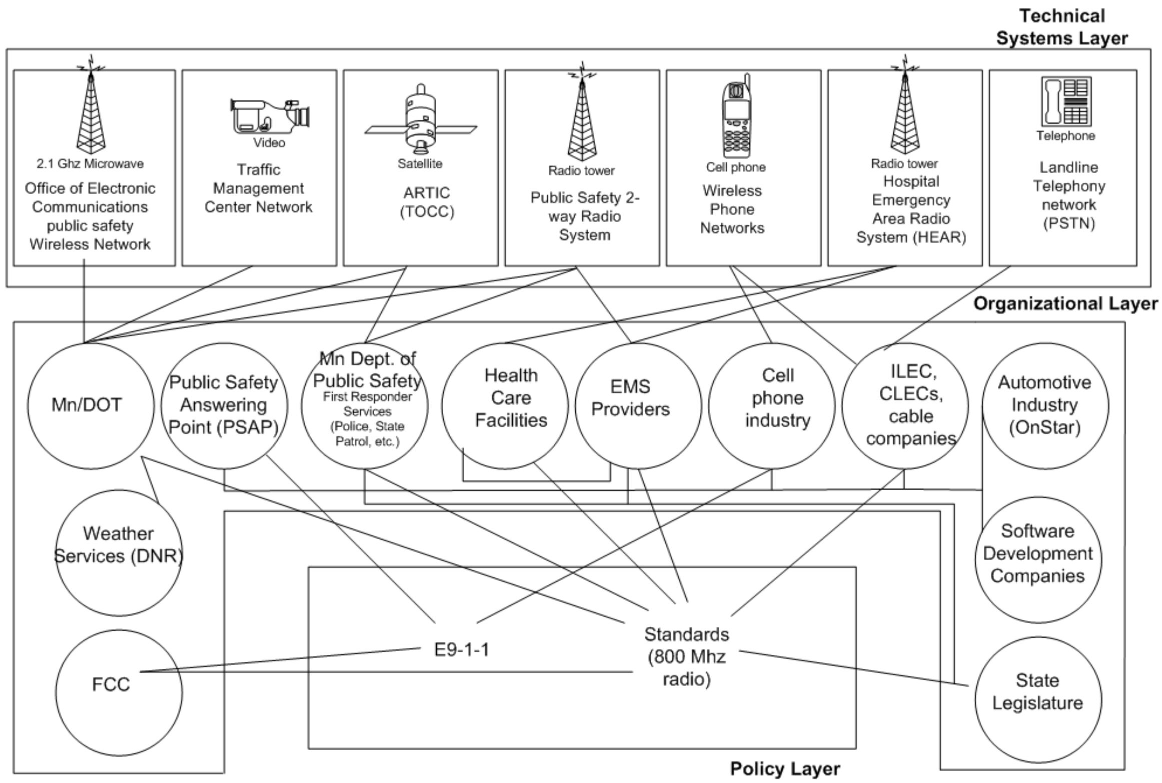

Figure 2. EMS in Rural Minnesota

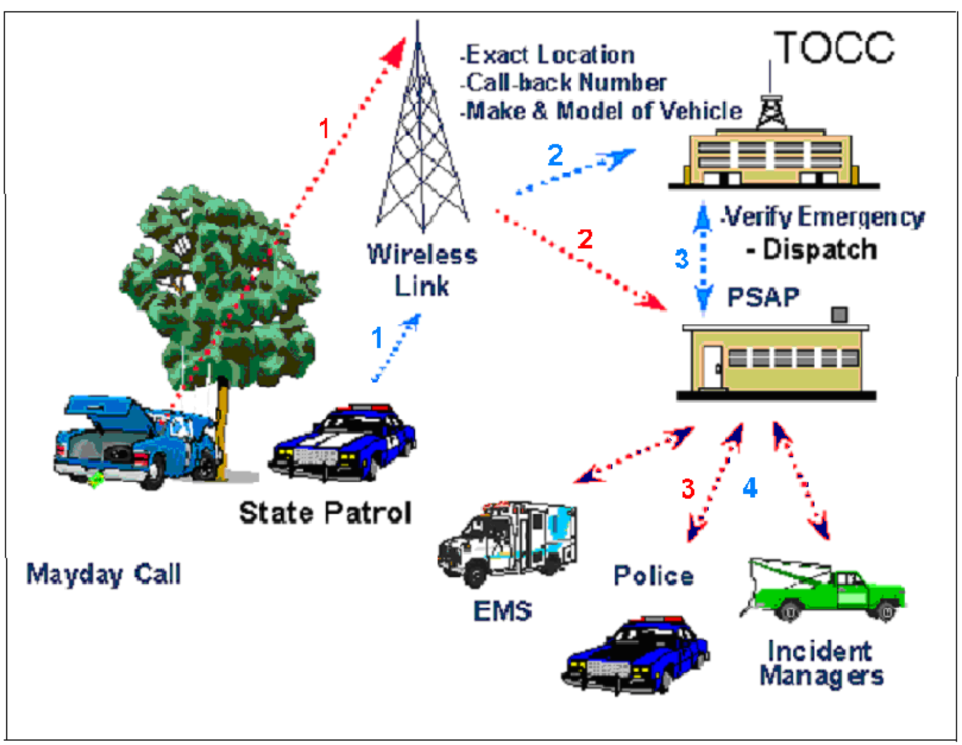

Figure 3. Wireless Mayday Call Routing Procedure in Rural Minnesota

EMS Ontology (Version 1.0)

The socio-technical framework described above represents an architectural blueprint for version 1.0 of EMS ontology. All or some of the components and their relationships in this architecture can be translated into an ontological framework. The first step in developing the ontology is to define classes As a general proposition, these classes are based on the framework and process identified in Figure 2 and Figure 3. The superclasses are determined first followed by subclasses. Five super-classes were defined and these are: (1) Incident Report, (2) Incident Information Acquisition, (3) Routing or Dispatch, (4) Response and Coordination, and (5) Data Management. Figure 4 provides a tree diagram representation of the ontology developed for Wireless EMS in Rural Minnesota. The number of superclasses may increase as the case study evolves. Their current representation in Protégé system can be seen in Figure 5.

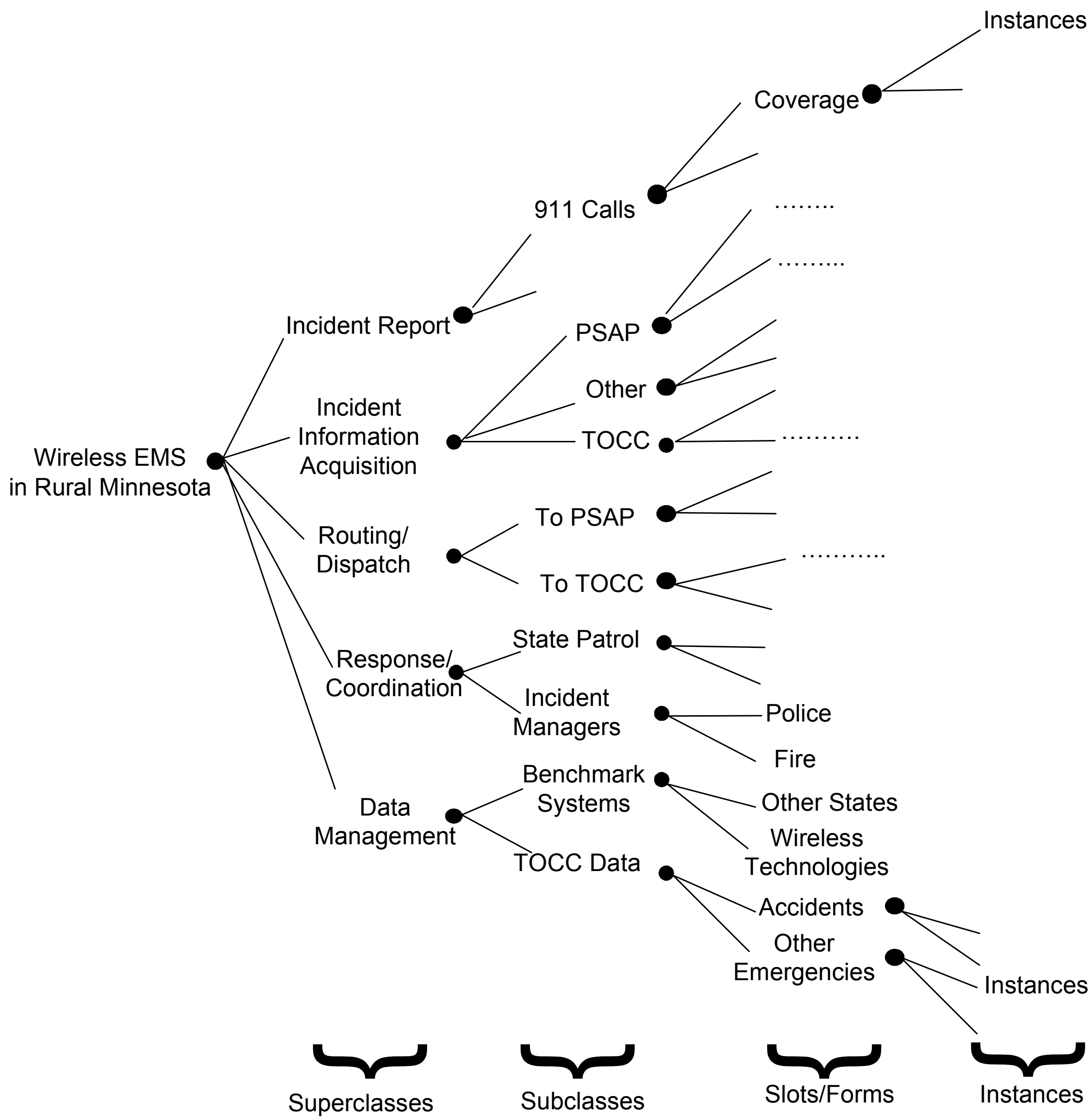

Figure 4. Tree Diagram of Wireless EMS Ontology for Rural Minnesota

At the current stage of the development all superclasses have few subclasses. However, more subclasses can be added to the superclasses through updated versions of the ontology since the emergency management in rural Minnesota is an emerging system.

Many super/subclasses are created as a manifestation from the wireless mayday call procedure described above. For example, the subclasses called “911 Calls”, “Automatic Crash Notification”, and “Radio Communication” under the *Incident_Report* superclass are part of the wireless mayday call routing procedure as well as the technical systems layer of the Socio-technical framework. On the other hand, there are subclasses that are not directly related to both Socio-technical framework and mayday call routing procedure. One of them is “Benchmark Systems” under the *Data_Management* superclass. This subclass plays an important role in knowledgebase development with crucial nationwide information attached for comparison. That is, it establishes the basis for communicating performance, another key goal for the EMS ontology.

A second step in the Protégé knowledge acquisition system is to define the *Slots* with their value type and cardinality rules. This is an important process, as the instances recorded later must comply with these rules. Some documentation in the form of text can also be included for each slot. After defining all the *Slots* for each subclass, Protégé automatically generates *Forms* for acquiring data as *Instances*.

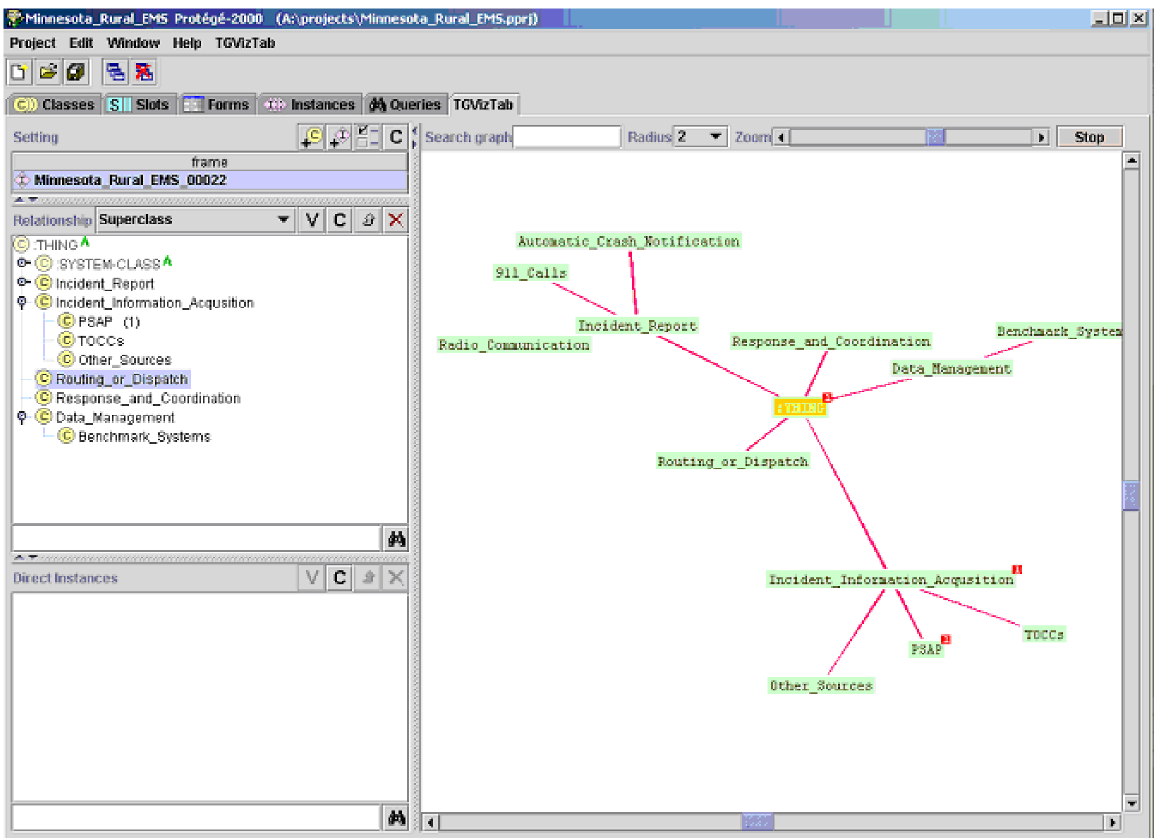

Figure 5. Wireless EMS Ontology for Rural Minnesota (Protégé 2000)

Next Steps and Directions

During the early summer 2003, the second case study will be conducted and the ontology applied to data and information obtained. This ontology will be presented in a web-enabled format and communicated to case study participants. Following completion of the second case study, a series of performance simulations will be conducted using ARENA business software. Findings from this analysis will be integrated into the ontology framework as well.

Local stakeholders were briefed on the ontology development in late 2002, and expressed support for its use; however, several steps remain to integrate the system into a paper-dominated means of characterizing and reporting on system performance. The ultimate goal of this research is to create a new means to articulate, measure, and drive development of emergent systems, such as wireless EMS. In this sense, the ontology provides a graphically-oriented evaluation element to system analysis, thereby facilitating knowledge sharing among system providers. That is, ontologies (including performance information) could be made available on the web (and through online research report channels) such that the data could be available for benchmarking, research investigations, and technology/knowledge transfer.

Indeed, from a research perspective, the EMS ontology being developed is aimed to contribute to the increasingly active area of ontological-driven research (see Mayr, 2002; Weber, 2002). The approach in this EMS research is particularly suited to enhancing the fields understanding of how a robust ontology can be devised and shared using a platform impendent software program (Protégé), and done so in a manner that stresses data reporting on systems performance. It is worth noting that domain areas such as bioinformatics have moved aggressively ahead in using ontologies in this manner (though the nature of "performance" data can be quite different) (see Grosso, et. al, 1999). Expanding this dynamic use of ontologies is a worthy pursuit for the field of IS, and one that will have benefit to many domain areas as well as advancement of the field in general.

Acknowledgements

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