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Web Services for Emergencies: Multi-transport, Multi-cloud, Multi-role

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***Abstract*—In an emergency, response services require guaranteed availability regardless of failures in data transport layer and cloud service providers. In the work-in-progress reported here, we discuss three projects that have requirements that stress web infrastructure in preparing for and responding to emergencies. Our goal is to highlight the tradeoffs in costs and benefits of web services in each case, and to provide an indication of our approaches in addressing these issues.**

I. Introduction

Compositions of web services in an Emergency Platform require careful structuring, coupled with intelligent client failover algorithms. This work in progress considers the common elements of three different Emergency Platforms from the perspective of their web services infrastructure. Each must accommodate various transport layers being seamlessly melded, and allow data sources and analyses to operate in multiple clouds. Additionally, the user cannot be overly aware of where those resources are located, and the platform must allow for user interactions at various levels of access permissions and device fidelity.

A. Project 1: Nal-Pal

The first, and simplest, project is an application called Nal-Pal which is designed to pair individuals who need help in responding to an opiate overdose with people who have Naloxone response kits available. In British Columbia, and other parts of North America, we are in the throes of a public health crisis. Opiate users are overdosing in numbers never before seen, in large part due to synthetic opiates infiltrating the drug supply. On Vancouver Island, where we are located, thousands of people have taken Naloxone training courses and been given an emergency response kit that contains injectable Naloxone which can rapidly reverse the symptoms of an overdose, but only if administered in time. The challenge is to get those kits to the people that need them, faster than even an ambulance can respond. The initial design was a simple pub/sub web service that was envisioned to notify everyone on the Nal-Pal system where a kit was needed.

There are several problems with this solution, many of the opiate users who will be calling for help are given older Android cellphones at the shelters. These phones are not provided with a data plan and only offer basic calling and texting features. Consequently, the application must be able to smoothly scale to use simple text messaging as a data layer in an emergency response, as shown in Figure 1.

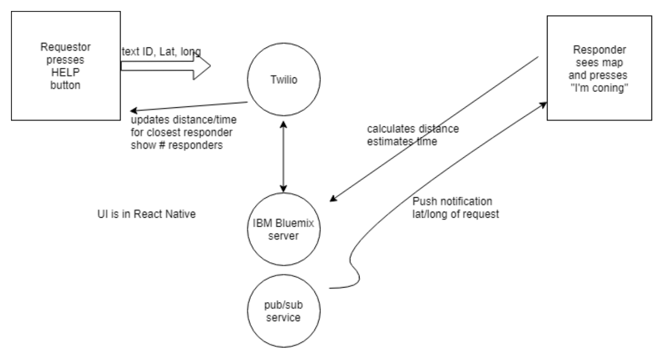

Fig. 1. Block diagram of SMS, all text messages are sent by the app rather than being entered as text by the user. In this version of the scenario the responder is on a regular data network rather than depending on text messaging

B. Project 2: Distributed Data Analytics Platform

The second project has a much more complicated infrastructure for analyzing data that pertains to emergencies, targeted primarily at researchers in advance of a disaster, but as we'll see in the third project, this interaction becomes critical to move into real-time systems during a disaster. In advance, however, the primary challenge is that data from the different partner organizations exists in different clouds. In our initial example, data on tsunami modeling and early warning has been collected by our partner Ocean Networks Canada, and exists primarily in the Compute Canada cloud. Other data that is pertinent to analysis exists on the Amazon Web Services cloud (primarily satellite imagery) and services exist on the IBM cloud.

Tying all of these into a federated data analytics offering that is accessible and easy to use for researchers at each of the partner organizations is the goal of this project. This system includes public, crowd-sourced reporting on harmful algae blooms (such as red tides), so role-based permissions will be critical to enabling participatory data collection and access, while securing the data. (Figure 2.)

C. Project 3: The EOC of the Future

The third project is a longer-term effort that was presented as a vision of an Emergency Operations Center (EOC) of the

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Fig. 2. On the isolated BC coastline, reporting of red tides from members of the public fills in critical gaps in data

future at a disaster preparedness conference of the UN Office of Outer Space Affairs in November 2017. The core insight is that in an emergency, too much time is dedicated to simply getting all the individuals who are tasked with responding to the emergency into the same room. Combined with this is the cost of outfitting a state-of-the-art EOC with fiber networks and wall displays, the cost is prohibitive to the extent that rural EOC facilities are often little more than a bank of phones and a whiteboard.

As we enter the era of low-earth-orbit satellite communications [1], disaster-resilient connectivity is quickly becoming a non-issue. As mobile devices soon begin to use these networks, and provide enough on-board capability to allow augmented-reality group conferencing, the concept of a physical EOC will quickly become dated. This project explores the challenges in directly connecting researchers and data products from our second project to inform emergency response personnel, wherever they may be located, of the latest analyses and simulations to provide augmented decision support in the emergency response.

Fig. 3. Emergency Operations Center of the future, work presented to the UN Office Of Outer Space Affairs [2]

II. Background and Related Work

Scalable emergency response systems often leverage low power wireless sensor networks composed with multiple web services architectures [3]. Social (multi)media can also capture situational information in form of pictures, videos, or text messages. Recent approaches to emergency management platforms have incorporated multimedia metadata to cluster the set of sub-events related to an emergency situation [4].

Additional compositions of mobile, GIS, and web base systems have shown to be effective in emergency situations involving spatial data analytics [5]. In an emergency situation, Emergency Officers (EOs) must manage multiple streams of relevant information—such as demographic data, weather forecasts, sensor data, available transportation means, land use and cover statistics or values. This is often complicated by the fact that multiple agencies not only own the relevant data but possess specific elements of emergency related knowledge [6]. Proposals for Group Decision Support Systems (GDSS) coordinate interests of all parties, resolve conflicts and generate a resource deployment for efficient Emergency Operations [7]

Many data-driven techniques have been applied to improve situation awareness as well as in addressing users information needs in disaster management, including data-mining and machine-learning techniques in disaster management [8]. Even within the context of Emergency Management platforms, predicting Web service interactions such as composition and substitution is critical, and deep-learning approaches have been applied to learn latent service features [9].

III. Nal Pal: guaranteed availability

Nal-Pal is a service that must always be available, despite the fact that many prospective users of the system only sporadically have data connectivity. The solution is to use text messages as an ad-hoc data layer. In order to achieve this, we use the Twilio web service as a front-end to our standard pub/sub service and our IBM-hosted application server. From the user perspective, the application just works and the logic to failover to the text message service is contained entirely within the application in this case. Some of the challenges yet to be resolved are what to do in the case of slow message delivery and what to do about erratic data connectivity. The metric is not simply ”is there service” but rather what the performance characteristics of that service are.

The other complication is that over 70 percent of recent deaths are due to people using alone. In some cases these individuals are reluctant to call for help because in shelter and shared housing situations they may be balancing overdose help with being evicted. For these users, our community partners have suggested setting up a ”safe responders list” rather than distributing alerts to the Nal-Pal list as a whole. This complicates our pub/sub model by introducing per-user preferences for who alerts go out to.

Nal-Pal is an application that has both life and death ramifications, a user population that is often not forgiving of application issues, and a community model that must be approached with great sensitivity. As an application development environment this poses many challenges, but the reward is directly saving lives.

IV. Distributed Analytics platform: multi-cloud

Project 2 is different, but shares common needs, with Project 1 (Nal-Pal). Here, the challenge is not time-sensitive guaranteed availability, but rather integrating a complex set of services across multiple data sources hosted on multiple cloud providers. Doing so in a way that allows researchers to construct analyses using the disparate data sources without necessarily understanding the architecture of the underlying web services.

The major data sources and operations to be integrated are:

- Satellite imagery on the AWS cloud
- Ocean sensor data on the Ocean Networks Canada system, but generally ported over to the Compute Canada cloud
- Pub/sub services, database, and analytics services on the IBM cloud
- Processing nodes on the Compute Canada cloud, including GPU resources

These analyses are generally not in real-time, although in the case of some applications immediate processing is required, eventually leading to a real-time system as described in project 3 below.

Ocean Networks Canada (ONC) provide a rich network of ocean sensor data. Researchers use that data, and associated data products like digital elevation models, to both analyze historical data and write simulation and predictive software to address future potential emergencies. We work most closely with the near-field tsunami team. In our current iteration of the project we are focused on simulation data as it effects a city of the West coast of Vancouver Island, Port Alberni. The geography of this region leads to an extreme tsunami risk in the event of earthquakes along the Cascadia subduction zone off the coast. Within 30-40 minutes after an earthquake, it is anticipated that Port Alberni will be struck by a tsunami; accordingly, ONC has a rich sensor network in place to detect such events, including radar, bottom pressure recorders, and GNSS elevation data. The modeling of these events can lead to predictions of changes in water height and currents resulting from the events, and are used for simulation and training, including virtual reality-based simulations.

MEOPAR, the Marine Environmental Observation, Prediction and Response network, is an independent non-profit organization focused on bringing together academia and industry in areas of marine risk and resilience. In the project that we are most closely involved, MEOPAR operates a network of sensors and data reporting infrastructure for algal blooms.

These projects are conceptually related projects in that they have historically had a hard time sharing large volumes of data. Although the ocean sensors run by ONC runs and maintained by MEOPAR and their industry partners are similar, the data resides on different networks and they are used for different types of inquiries. Our earth observation partner, Urthecast, has yet another layer of satellite imagery data which resides in yet a third location.

V. EOC of the Future: guaranteed real-time analytics

In November, 2017 the UN Office of Outer Space Affairs (UNOOSA) held a meeting on disaster preparedness. As part of that, the team showed a video of our progress towards an emergency operations center of the future. An EOC today, in a major urban area, is often a multi-million dollar hard-wired response center. But despite the impressive connectivity and wall-to-wall displays, the first stage of an emergency response still depends on people, the area commanders, physically diverting from their normal lives to the EOC response center.

Our solution to this challenge rests on two key developments. The first is the forthcoming deployment of low-earth-orbit satellite communications, the second the rapid evolution of mobile devices as AR/VR teleconferencing platforms. The first networks will come into service in 2019 by a company called OneWeb, followed shortly thereafter by a larger fleet from SpaceX. These satellites, much closer than current communications satellites, will be able to communicate with cellular technology similar to today's mobile phones and provide high bandwidth voice and data communications that are largely protected from terrestrial service disruptions, even more so than hard-wired fiber lines. Consequently, the connectivity benefits of today's EOCs will be contained in a device you can hold in your hand. And those non-urban areas that do not have well-funded EOCs will suddenly be on an even playing field with more established response centers.

The ability to have distributed personnel form part of the EOC team through high-fidelity videoconferencing is not only beneficial to the speed of response, but to the quality and customization of information products available to responders. If a local emergency occurs, experts from around the province are available virtually to assist. If a broader emergency occurs, keeping the response centers synchronized becomes much easier.

It is in this realm that the research platform described in project 2 begins to have real-time requirements. If the researchers and experts can make analyses available to responders as an emergency occurs, and the shared data platform for coordinating an emergency response allows these reports to be processed and managed in a way that responders can use them, then everyone is operating with more and better information.

The proposed augmented reality EOC contains services that must be real-time - chat, voice communications, etc. But it also imposes higher processing requirements on even those data analytics elements that researchers begin to use today. In AR and VR, a large part of the power of the platform is to draw on expectations and experiences developed while navigating the real world. This allows user interfaces to take on a solidity and dependability that is unparalleled but it also imposes performance requirements that cannot today be met. When you grab a slider in VR and move it, you expect it to move like a real-world object. If it stutters and moves only when processing returns to that node it breaks an expectation and usability suffers.

VI. Challenges

Our planning moves from today's solutions in project 1, to tomorrow's platform in project 2, to the future several years distant in project 3. In each case, the challenges from a web services perspective are met by flexible framework that must consider three sources of variation: flexibility in data transport layers, operation over multiple servers and cloud providers, and accommodating of multiple roles of users and prioritizing access based on those roles.

A. Multi-transport

The example from project 1 of moving smoothly from a web transport layer to data over text message is an instance of this smooth failover, but it doesn't illustrate all of the principles that must be kept in mind. Where possible, transport layer changes must be:

- Seamless, or even better invisible, to users
- Where functionality must differ, those differences be easily understandable to users
- Failover must not just be on complete service failure, but on flexible criteria of response time, cost, and functionality differences

B. Multi-cloud

The requirement for multi-cloud comes from two main places - a guaranteed availability perspective since cloud providers can have outages, and from a perspective of where the relevant data resides.

In terms of data, in order to do some processing it may be necessary to move pieces of the data around. From a cost perspective, this should be minimized since most cloud providers charge for data movements in and out of their cloud but not between servers on the same cloud. If you are going to be doing time-sensitive operations on combined data sets then some data must be moved. It is equally important to evaluate which data a user needs access and to place the main processing on that cloud where most of the data they'll need resides, although if processing requires specialized resources such as GPUs that are not available on that cloud then more data movement may be required.

The multiple hosting for guaranteed availability is in many ways more interesting. The failover scenarios must not only be on the services the client is accessing, but on the client itself - if site one doesn't respond or is slow only the client can know to failover to site two. This list must be published by the initial service entry point, though, so that it can be updated as the platform evolves.

C. Multi-role

Web services today must deal with a variety of roles, the primary difference in the emergency responder situations is that those roles change based on the nature of the emergency. If there is an earthquake, then the general public reporting a red tide event is not only a distraction but it could potentially divert system resources away from emergency responders. If one region is having a localized emergency then even responders in other regions must have their traffic and resource requests deprioritized.

Roles in an emergency situation are often also hierarchical. The logistics commander in a local EOC, for instance, is already dealing with an overwhelming deluge of information to process and will probably not be contactable by a researcher directly, even if that person has valuable information to contribute. It will be necessary to percolate that information through other members of the response team. Chat communication is preferable to voice communication for that same reason, and the group chats must also adhere to hierarchies of information access which differ by organization, by role within that organization, and even by the type of emergency.

VII. Conclusion

Outside of emergency management, rarely are web services subject to such an array of requirements in terms of guaranteed availability, performance, and flexible data management. These requirements are exacerbated by the fact that human lives are at stake should systems not perform as expected. These requirements, and the ramifications of not meeting them, make emergency response systems an appropriate venue in which to talk about web services requirements.

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