

ImmuNet: Improved immunization of children through cellular network technology

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Abstract—Vaccination distribution and tracking, especially in remote areas in the developing world, is an important problem that can benefit from recent technological improvements in attaining more effective distribution mechanisms. In this paper we describe ImmuNet, a system that utilizes cellular network technology and allows rapid determination of immune status; reliable updates of vaccination records and quick targeted dissemination of vaccination availability in rural areas. In Summer 2012 our research team traveled for three weeks to the rural village of Macha, Zambia to deploy one of ImmuNet’s modules and also to conduct interviews to gain understanding for immunization practices in remote rural areas.

I. PROBLEM MOTIVATION

While vaccination has lead to the successful eradication of a number of diseases in the developed world, developing countries still fall behind in implementing high-coverage immunization strategies. According to statistics from the World Health Organization, 1.5 million children died in 2010 from diseases preventable by vaccines. The highest percentage, 42%, of the cases were in the African region and 29% were in South East Asia. Most of the deaths were caused by Hib Meningitis, Measles, Pneumonia and Tetanus; all of these are diseases that can be prevented through vaccination. In many cases vaccines are available; however, vaccination schedules are difficult to enforce due to missing or incomplete information about vaccination availability and individuals who need immunization.

There is increased effort in incorporating Information and Communication Technology (ICT) to improve vaccination distribution to children and infants [1], [2]; however, such systems are often designed according to western models and operate under assumptions that do not hold in developing countries. One typical assumption is that personal immunization history can be kept easily by the health workers as they perform vaccinations. Our work with the immunization staff from the Mission Hospital at Macha, Zambia, unveils that immunization clinics are often understaffed and keeping personal records along with the day-to-day immunization routines is a very time consuming and challenging task.

Another common assumption is that digitalizing immunization records would help significantly improve the efficiency of storing and accessing patients data. Technology including such that facilitates digital data entry is just being introduced in the developing world. Thus, otherwise skillful health care staff often lacks basic technical skills such as typing. In

fact, our work in Macha shows that at best people can hunt and peck and these are typically people involved with IT, not the health workers. As a result, digital data entry could turn into an additional hurdle that needs to be tackled by the already overworked health care staff. Furthermore, while adopting digital data entry, the immunization clinics still need to maintain their traditional practices of paper data entry, as this paper work is required on regular basis by the government officials. This results in doubling the effort put into keeping immunization history.

Challenges in distribution of vaccines are not only related to data entry and personal immunization history but also to outreach, especially to parents with children under the age of five, who do not attend school yet. Traditionally, information about vaccination schedules and availability is distributed through posters, word of mouth and in Macha, through the local community radio. Information is typically disseminated a few days or even weeks in advance, and as one of our interviewees from Macha shares, “It is very easy to forget which day exactly was vaccination day and miss an immunization”. Thus, having a technology that is intuitive to people to help remind them for upcoming immunization events is of great importance.

To address these challenges and facilitate efficient distribution of vaccinations, we propose ImmuNet, a system that leverages cellular network technology and database tracking to keep individual immunization records. As most mandatory vaccinations occur between the age of 0 and 5 years, ImmuNet is designed for improved distribution of vaccinations to infants and children under the age of five. This focus, coupled with the specific vaccination practices in developing countries, poses unique challenges in the system design. To operate in rural areas with understaffed immunization personnel, the system enables collection of personal data in digital format that is submitted either by health workers or directly by the parents. By utilizing local cellular network infrastructure, the system provides prompt dissemination of information for vaccine availability and schedules in the form of text messages. ImmuNet can also record users’ network association time and location and thus build patient interaction graphs to predict disease spread patterns and vaccination needs. Based on these interaction graphs, ImmuNet provides an alert system in the form of a heat-map that notifies health workers for high risk regions that need vaccinations.

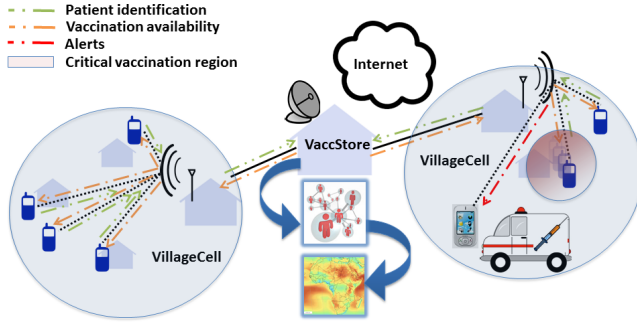


Fig. 1. ImmuNet Architecture: ImmuNet uses *VillageCell* as a cellular network platform and *VaccStore* as a database to collect patient identification, to distribute immunization information and to generate high-risk alerts.

II. SYSTEM OVERVIEW

ImmuNet (Fig. 1) consists of two main components – a database called *VaccStore* and a local GSM network called *VillageCell*. While *VaccStore* is responsible for storing patient data, *VillageCell* is the network that provides connection with the patients. An engine, that runs on top of *VaccStore* is responsible for collecting patient immunization and mobility data from the network and sending alerts and reminders based on this data.

VaccStore. A key part of ImmuNet is the *VaccStore* database that stores personal biometric and identification data for each person, as available, and their immunization status. We implement *VaccStore* in MySQL, one of the most commonly used relational database management systems. A system that allows data to be submitted directly by the patients, inherently needs to support search on a noisy dataset. Such challenge cannot be handled with a traditional relational database solution. Therefore *VaccStore* extends this traditional paradigm to adapt to the requirements presented in the context of vaccination in developing regions. There are two main ways in which we extend the relational database paradigm: first we introduce a probabilistic data model to capture incomplete or uncertain data and, second, we incorporate basic diffusion models to capture the spread of diseases and influence and to create a *social* database.

VillageCell. We augment the original design of *VillageCell*, first proposed in [3], to a system that as of July 2012 covers an area of about 35 square kilometers in the village of Macha, Zambia. The system deployed in Macha, uses two RangeNetworks base stations that operate in the 1800 MHz band and each provides a coverage range of 5-7 kilometers. *VillageCell* uses open source and free software. Each base station runs an implementation of the GSM stack called OpenBTS. Calls are routed within or outside the local GSM network through Private Branch Exchange (PBX) software called FreeSwitch. To provide text messaging functionality in the system we use *smqueue*, which provides a store and forward SMS queue. This functionality is extremely important, as we expect that users will typically not be in range at all times, thus, their messages can be delivered in a delay tolerant fashion whenever they re-associate with *VillageCell*. The two

VillageCell base stations deployed in Macha are connected over a wireless backhaul, which is already available through the village wireless infrastructure¹.

III. INTERVIEWS IN MACHA

During our visit in Macha in June/July 2012, we conducted interviews with 25 people from the area at the age of 17 to 48 years, to gain better understanding of cellphone usage in rural areas as well as people's perception of immunizations. Each interview was conducted in person between one interviewer and one interviewee. The interviewee's participation was voluntary and no material award was associated with the participation. To facilitate the interview process, we hired a woman from the community to introduce us to potential interviewees and help with translation. With interviewees' consent, 17 of the interviews were audio recorded.

The results from our interviews unveil that the benefit from immunizations is very well understood in the local community. All the people interviewed had been immunized when they were young and some of them perceive immunization as a "tradition" that needs to be followed, while others are keen to immunize their children, having experienced themselves the benefits of immunization in previous disease outbreaks, when they "did not suffer from the corresponding disease" because they were immunized. Only one of the participants who had a child under her care, did not do all recommended immunizations; all other participants had immunized all their children against all recommended diseases.

Cellphone usage too is widely adopted by people from the community as well as health workers. 24 of the 25 interviewees owned at least one cellphone and SIM card and all the interviewees were very accustomed to using basic functionality such as call and text messaging. 24 of the participants were excited about the idea for using their cellphone to receive SMS reminders for upcoming immunizations for their children.

IV. CONCLUSION

Incorporating technology for improved health care, especially in remote areas in the developing world, has had tremendous success over the last few years. ImmuNet continues in this direction by providing technology available at no additional end user cost for improved distribution of vaccines. Our work in the rural village of Macha, Zambia establishes distribution of vaccines as an important problem that can benefit from technological innovations. We are hopeful that by using a widespread technology such as cellphones, our system has great potential to improve the distribution of vaccines in the developing world.

REFERENCES

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