Management of E-Health Networks for Disease Control: A Global Perspective[1]

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Abstract— **While network management has been intensively and thoroughly investigated in the past, research on and developments in the area of E-Business management is still evolving. E-Health, being one of the most significant and complex types of E-Business, offers some interesting scenarios from the perspective of layered management frameworks. This paper examines one aspect of E-Health, namely public health as illustrated from the viewpoint of pandemic control. We present a five-layered framework to address the management issues of E-Health based on the example of a Pandemic Control System.**

Index Terms— Framework, E-Health, Public Health, Pandemic Control, Information and Communication Technology

I. Introduction

Recent occurrences of epidemics like the *Severe Acute Respiratory Syndrome* (SARS) or the *Avian Influenza* clearly display the threat and seriousness of global diseases. The steadily growing globalization makes it difficult to contain epidemics to a certain region: due to increased international travel and trade they can easily become a global threat; hence they are called pandemics. Furthermore, global disease threats are not limited to natural causes anymore. The possibility of terrorists using biological weapons has become very real. Although many countries are now working on their own security frameworks, a global problem of this magnitude requires a global solution. For these reasons, a global multi-layered framework must be designed and implemented.

This paper summarizes the basic principles of such a framework for pandemic control and reviews the current efforts in evolving a global solution to the problem. The latter point mainly refers to existing national or international networks for diseases and pandemics implemented and maintained by organizations such as the *World Health Organization* (WHO), the *European Centre for Prevention and Disease Control* (ECDC), and the *Centers for Prevention and Disease Control* (CDC) in the US. One main goal is to support countries introducing pandemic response systems with respect to their individual characteristics and requirements. We furthermore emphasize the necessity of international communication and information exchange between the national systems.

This paper is organized as follows: first, we briefly discuss the background of pandemics. We then discuss pandemic control as a disaster management strategy akin to natural disasters and terrorist attacks using biological or chemical weapons ("bioterrorism"). This is followed by a general overview of existing approaches (i.e., disease surveillance networks). Finally, we discuss the layered management strategy as illustrated with a management solution based on global information and communication technologies (ICT).

II. Background

Throughout history, many pandemics have struck mankind, sometimes more, sometimes less severely. History states the devastating impact a pandemic might have regarding human casualties, as well as on social, economical and ecological systems. Three of the most notorious pandemics, the *Black Death* in the 14th century, the *Spanish Flu* in 1918/1919 and the *Acute Immune Deficiency Syndrome* (AIDS) in the 20th and 21st century, clearly demonstrate the possible seriousness and scope of a pandemic. Besides these major outbreaks, however, there are many smaller occurrences: WHO has verified more than 900 epidemic events between January 2001 and September 2005 alone [7].

Epidemics and Pandemics have numerous destructive consequences, among which are: loss of productive workforce, destabilization (e.g., chaos, anarchy, fight over limited resources), and other social effects (e.g., persecutions, physical and psychological isolation).

Due the long period since the last pandemic occurred (excluding AIDS), it is believed that another pandemic is possibly imminent. The occurrence of the Avian Flu (especially the appearance of the H5N1 variant), with its high mortality rate among poultry and humans and its fast spread since its re-emergence in 2003, strengthened this belief. According to WHO [7], "it is 'only a matter of time' until the deadly H5N1 virus becomes capable of human-to-human transmission and causes global chaos".

The impact of such a pandemic might be unprecedented in history: the Lowy Institute's report, titled 'Global Macroeconomic Consequences of Pandemic Influenza', states

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[1] This paper is partly based on an earlier publication by the authors [4]. While in the former publication emphasis is placed on ICT in a multi-layered framework, this paper discusses all layers of the framework.

that the worst case scenario could result in as many as 142 million casualties worldwide and global economic losses run to $4.4 trillion ("ultra scenario") [1]. But it says even a mild pandemic could kill 1.4 million people and cost $330 billion.

Particularly, countries with poor sanitary conditions and limited or non-existent resources for encountering and defeating such diseases are likely to be severely affected by them. In addition to that, the steadily increasing international travel and exchange of goods due to globalization accelerate the spread of epidemics, turning them into pandemics easily. This requires a tight international cooperation (e.g., [3]) on the one hand, and a strengthening and extending national response capacities (e.g., [11]) on the other hand.

III. Disaster Management

This section presents the problem of E-Health disaster management in the context of an outbreak of a pandemic.

A. Phases

The occurrence of a communicable disease and its response

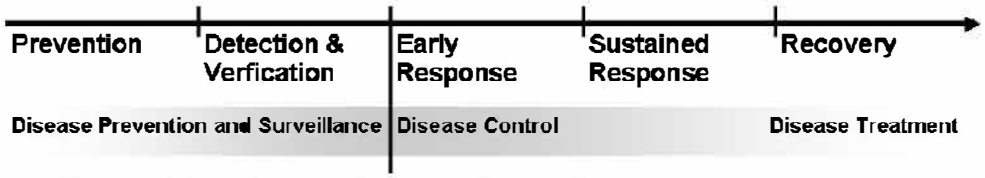

Fig. 1: Chronological phases of a disease outbreak cycle (taken from [5], extended and modified)

can be divided into five chronological phases (see Fig. 1).

The first phase is not directly related to an outbreak, but can hopefully prevent the outbreak from even happening in the first place: *disease prevention* is the hindering of the occurrence of diseases in a susceptible population. Prevention is the most important phase since a successful prevention results in the saving of many lives as well avoiding the aforementioned destructive consequences. Unfortunately, the assessment of success of disease prevention is very difficult.

If, however, the prevention process is not successful, the *detection and verification* of an outbreak takes place. This phase is important for a fast and efficient response. Once a disease has been detected and identified, the response phase begins. The response phase can be divided into two individual sub-phases that have individual requirements and need.

First, the *early response* phase starts. The main goal of this phase is *disease control*, which means all ongoing operations that are designed to reduce an outbreak or disease (i.e., minimize the initial impact and contain the outbreak). This includes sending detection, verification and containment units to affected regions, increasing the short-term production and distribution of vaccines, informing possibly threatened population groups, etc.

Second, right after the early response phase the *sustained response* phase begins. Here, actions like replenishment of medical supplies, mental health support, etc. are required. The emphasis of this phase is on *disease treatment*, which refers to specific procedures used for the cure of the disease. This phase, however, does also include further disease control. For this reason, the transition from phase three into phase four is rather seamless.

Finally, there is the *recovery* phase that covers further treatment of patients, assessment of the response processes and accordant improvements of the processes, and possibly the recovery of economies and societies.

The WHO has introduced a different model with different objectives in each phase [13]:

- Pre-pandemic: reduce opportunities for human infection and strengthen the early warning system,
- Emergence of a pandemic virus: contain or delay at the source, and
- Pandemic declared and spreading internationally: reduce morbidity, mortality, and social disruption and conduct research to guide response measures.

Similarly to our descriptions of the phases, they further state five categories of general actions to be taken to accomplish the public health goals: planning and coordination, situation monitoring and assessment, prevention and containment, health system response, and communications.

This model was especially designed for pandemics while our model is more general and can be adjusted to all magnitudes of outbreaks.

Depending on the individual disease and its grade of progress (in the sense of both, spread and mutation), different strategies and technologies are to be employed. Already being a pandemic, AIDS, for example, does not require an immediate response to contain it to certain regions (since it has already spread all over the world). In this case, a *sustained response* with the goal of treatment and extinction is appropriate. Other diseases like SARS, however, require a quick response in order to contain the outbreak (and avoid a spread as it happened in the case of AIDS); this would rather be *early response* and is covered by our focus on pandemic reduction or containment.

B. Stakeholders

We identified the following stakeholders that must be involved in the implementation and, even more importantly, in the outbreak response actions:

- General public,
- Government and related agencies,
- Health and healthcare organizations, agencies and professionals,
- Laboratories and research institutes,
- First responders of emergencies (e.g., police),
- Travel and tourist agencies and personnel,
- Animal health and control agencies,

- Agricultural and environmental professionals (incl. farmers),
- News broadcast companies and education personnel,
- ICT professionals and standards organizations.

The accurate and extensive integration of the stakeholders in the disease response is of utmost importance. Unfortunately, this is not everywhere and always the case. Especially the notification and instruction of the general public is often too slow and inferior. Moreover, the involvement of the general public usually is passive only (i.e., reduced to informing them), but could instead greatly benefit from an active integration (e.g., by providing the means for interactive communication).

Another important aspect is the consideration of often not directly involved parties, such as animal health agencies, since animals, for example, often can transmit contagious diseases, as it is the case with the Avian Flu. Especially migratory birds can be serious problem in this context (e.g., transmitting the disease to production animals) [15]. This requires the integration of veterinary and animal control agencies into the framework like, for example, the *World Organization of Animal Health*[2].

Additionally, national and international non-governmental organizations (NGOs) like the Red Cross[3] must be effectively incorporated in the process for they play a unique role in the area of health and provide support that "would not otherwise be available, particularly in reaching poor populations" [16].

Rippen identifies similar stakeholders but focuses on the threat of bioterrorism [5]. The modified model presented in her report is displayed in Fig. 3. We extended and adjusted this model to fit our work.

There are three main factors: Terrorists, Biological Agents, and Human Beings (as victims or targets). The capital letters describe overlaps: 'A' are traditional terrorist activities (e.g., 9/11 attack), 'B' is bioterrorism, and 'C' stands for natural outbreaks (e.g., SARS). The numbers refer to involved parties and groups: '1' refers to (federal) agencies for counter-terrorism (e.g., police), '2' are scientists and researchers that focus on biological agents (e.g., laboratories and agencies like the ECDC), and '3' means the general public.

The main goal must be to strengthen the abilities and capabilities of countries to respond to local outbreaks with regard to the international community: "building public health capacity [to deal with influenza] will lead to stronger national systems for alert and response linked to a comprehensive global alert and response system that will serve to protect us from whatever nature has in store for us in the future" [7].

IV. Existing Approaches

In this section, we would like to give a brief overview of already existing disease-related E-Health networks and other efforts to fight epidemics and pandemics. There have been many initiatives (e.g., raising money) in the past for individual diseases (e.g., a fund for AIDS for a particular region or

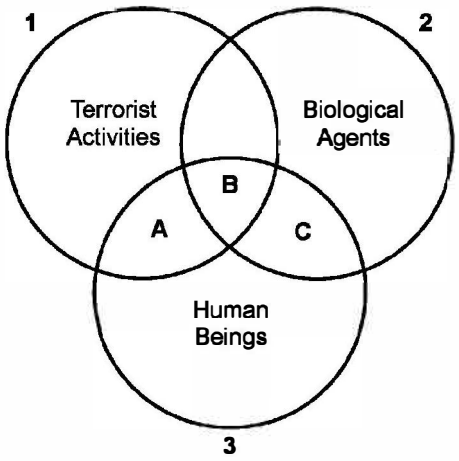

Figure 2: Involved factors of global disease threats (taken from [5], extended and modified)

population group) or the effects caused by specific events (e.g., for the tsunami in the Indian Ocean in December 2004 or hurricane "Katrina" in the US in 2005). For fighting the Avian Flu, in January 2006 the international community has pledged a total amount of $1.9 billion dollars [2].

The long-term goal, however, must be the establishment, maintenance and improvement of infrastructures and networks that are capable of dealing with all possible occurrences and events. Thus, we are examining already existing networks and other efforts to support this goal.

Three major organizations currently working on this topic are WHO[4], ECDC[5], and CDC[6]. There are a number of specialized content and application networks for disease surveillance and control, such as:

- **Surveillance Networks**: Antimicrobial resistance information bank[7], FluNet and RABNET[8], Global Salm-Surv[9], East Asia Network for HIV (EAN-HIV)
- **Community Alert Networks**: Outbreak verification list[10], Weekly Epidemiological Record[11], Health Alert Network (HAN)[12], APEC EINET[13],
- **Expert Systems**: US CDC NEDSS[14],
- **International Information Exchange and Communication Networks**: Health InterNetwork (HIN)[15], WHO GOARN[16],
- **Medical and Biological Research Networks:** Roland Koch Institute (RKI)[17],

[2] Organisation Mondiale de la Santé Animale (OIE): http://www.oie.int
[3] http://www.icrc.org/
[4] http://www.who.int/
[5] http://www.ecdc.eu.int/
[6] http://www.cdc.gov/
[7] http://oms2.b3e.jussieu.fr/arinfobank/
[8] http://gamapserver.who.int/GlobalAtlas/home.asp
[9] http://www.who.int/salmsurv/en/
[10] http://www.who.int/disease-outbreak-news/
[11] http://www.who.int/wer/
[12] http://www.phppo.cdc.gov/han/
[13] http://depts.washington.edu/einet/
[14] http://www.cdc.gov/nedss/
[15] http://www.healthinternetwork.net/
[16] http://www.who.int/csr/outbreaknetwork/
[17] http://www.rki.de/

- **Geographical Information Systems (GIS)**: WHO GIS & Mapping[18], GIS for Pandemic Surveillance and Control software developed in many countries.

WHO can be seen as the main supporter and coordinator of worldwide initiatives and efforts to such networks and frameworks. Since 1948, WHO has been responsible for the implementation of the International Health Regulations (IHR). These regulations were ratified by its 191 member states and were meant to strengthen the international use of epidemiological principles to detect, reduce or eliminate the sources from which infection spread.

According to [7], the WHO supports countries by "utilizing its international mandate, decentralized structure and capacity (six regional office hubs and 142 country offices), collective experience, and partnerships" (especially with GOARN).

The *Global Outbreak Alert and Response Network* (GOARN) is a good example for an international response network. GOARN was set up in 2000 and is a collaboration of more than 70 institutions and more than 180 technical partners in over 40 countries that pool human and technical resources for the rapid identification, confirmation and response to outbreaks of international importance ("strike force").

On the national level, there have also already been efforts to introduce *Emergency Response Plans* (ERP) in several countries. The 'National Pandemic Plan' of Germany by the Robert Koch Institute, for example, was developed in response to the WHO's 1999 postulation that all countries need to develop national plans [6]. This specific plan covers the following key points: mobile teams for fast outbreak investigation, clarify legal steps (travel restrictions, obligation to notify the authorities, etc.), improve and extend surveillance capacities and quality, sufficient quantities as well as continuous improvement of vaccines and antiviral for the population, regional pandemic response plans, hospital preparedness, and notification and information of population on low level (regional).

Some of these networks are expensive to maintain and poorer countries may not be able to afford them.

V. Layered Framework for E-Health Management

After having introduced the challenging problem of global disease control and having given an overview of existing approaches on a national and international level, we will now present our multi-layered framework to encounter and hopefully finally surmount this challenge.

A framework has to be realized both on national and international level. While international networks should provide the exchange of information based on standards and a well-defined ontology, on the national level of the framework most of the controls are to be implemented. We identified the following levels of implementation (see Fig. 4).

We will now take a closer look at the individual levels. The five levels are described in reversed order, since insufficient implementation of one particular level can and must be compensated by the level(s) above this particular level.

[18] http://www.who.int/health_mapping/

Figure 3: Five different levels of implementation

A. Level 5: ICT Level

The lowest level (level 5) is the information and communication technologies (ICT) level that refers to the infrastructure to enable communication and information exchange[19]. This especially requires the development of "coherent, comparable, harmonized and standardized policies with regard to: development of a disease control information systems policy framework, development of common definitions and a common data dictionary, establishment of mechanisms for information exchange and communication" [8], and development of services and applications for the dissemination of information.

It is especially recommended to use and extend already existing infrastructures instead of building completely new ones for this purpose (e.g., many countries already possess a wide spread cell phone infrastructure).

B. Levels 4 and 3: Application and Service Levels

The third and the fourth level are concerned with the translation of the above public health administrative functions to software requirements level. Services and applications have to be defined and implemented in order to support the levels above the ICT layer.

The purpose of these two levels is to provide experts, involved personnel, the general public, etc. with adequate information and means of communication and control regarding a current situation or development. These could be, for example, web services or the provision of broadcast channels (e.g., TV). The most important issue is to provide the *right target group* with the *right information* (communication or control mechanism, respectively) at the *right time*.

These two levels are closely related: since their (combined) purpose is to provide required means to execute their tasks. Users need appropriate services to perform tasks defined on the process level efficiently and effectively. These services mostly are realized using applications. An application can, however, be exchanged with another application that offers the same service, maybe even more conveniently. Furthermore, a service can be built on-top of several applications linked together (e.g., mash-ups in the case of web services). For

[19] This layer of the framework has already been thoroughly investigated and discussed in [4].

example, Geographical Information Systems (GIS) exist in many countries to track the outbreak of a pandemic.

C. Level 2: Process Level

The second level consists of organizational processes for dealing with cases concerning the public health, such as an outbreak of a disease. On this level, well-defined processes and steps must be defined to guarantee fast, correct, efficient and faultless actions before, during, and after an outbreak.

Examples are Emergency Response Plans that, at least in an optimal case, provide all involved organizations and personnel as well as the general public with information and directions (and maybe even assignments) so that every individual is aware of the current situation and knows what to do. Misinformation and/or the lack of knowledge of how to respond and act in a particular situation or under certain circumstances have often severe, if not even fatal, consequences.

With regard to the aforementioned examples on the application and service level, the CHO could, for example, have an exact number of casualties that need him or her to actually request the national medicine stockpile; or, an operator could have a *protocol* that requires him or her to immediately inform the superior officer if a specific alert comes up, etc. There can and should even exist protocols for the general public and public institutions such as schools, shopping malls, etc.

D. Level 1: Organizational Level

The highest and most abstract level is the organizational (international framework) or governmental (national framework) level. It is concerned with the definition and implementation of policies of public health at national and international levels.

Governments and organizations have to monitor and supervise the actions initiated and executed and guarantee the proper compliance with the protocols during an emergency. Another important aspect is, in case a situation is unexpected and cannot be dealt with using existing procedures, the quick and probably often spontaneous definition of new (or modification of existing) protocols as well as the passage of new laws if necessary.

E. Implementing the Framework

During the implementation, several obstacles have to be overcome on each level and in each phase (Fig 1 and Fig. 4). The goal is to identify and remove all barriers. We identify the following problems or constraints that mainly depend on local or individual conditions:

- Jurisdictional problems and bureaucracy,
- Societal and cultural problems,
- Technological and technical problems,
- Insufficient resources (incl. knowledge and workforces) and/or funding, and
- Insufficient decentralization of services.

For the framework to work most efficiently, the implementation and its activities must proceed with full respect for ethical standards, human rights, national and local laws, cultural sensitivities and traditions [16].

Obviously, the problems differ from country to country, and even from region to region. For this reason, the establishment and maintenance of national frameworks has to be adjusted to national and local needs. Nonetheless, nations that are not capable of implementing frameworks on their own must be assisted by other nations that typically are technologically and economically advanced.

While it is rather easy to implement a framework for a specific disease only, it is rather difficult to implement a framework for all possible diseases, especially on an international basis. An important part of the framework, however, is to establish an 'Emergency Response Network' (ERM) that is able to handle all occurring diseases, even or especially unknown ones. This is essential for "strong national public health systems and capacity, specific preparedness for key priority disease threats (e.g., diagnostics, therapies, vaccines, containment measures), and an effective international system and partnership for coordinated alert and response" [7]. In particular, the latter point requires the international community to agree on standards and ontologies.

There are, however, two more things to be considered when realizing a framework for pandemic control on a national level. First, the framework has to be adapted to and to be integrated into the existing infrastructure and E-Health systems. This is necessary for guaranteeing an efficient and reliable information exchange within the country.

Second, a framework for pandemic control does not solve all problems by its pure existence. As we pointed out before, prevention is the most important and best step of controlling or even preventing a pandemic. For this reason, a country also needs to improve its medical and sanitary conditions in general. This includes, for example, access to sources of clean water, proper sewage and infectious waste disposal and conscientious personal hygiene. Further factors are education, appropriate immunizations, and protective equipment like respirators, gloves, and outer clothing and building of national manufacturing capacities for vaccines etc. [10][14].

VI. Conclusions and Future Work

In this paper we described the possible seriousness of global diseases and the necessity to encounter them. We pointed out several requirements and important aspects to consider, and potential problems that might arise when implementing frameworks on national and international levels. We have illustrated the problem in the context of pandemic control involving a number of countries.

The main challenge when implementing a framework for pandemic control is to adapt it to the national and regional circumstances and requirements. This includes the usage of and integration of already existing (technical, medical, etc.) infrastructures and organizations, especially existing E-Health systems. Furthermore, we consider the involvement of the jurisdiction in the process of utmost importance: A government must be able to quickly react to imminent threats by passing new laws or adjusting existing ones (e.g., laws

regarding travel restrictions, quarantines, import and export restrictions, confinement of laying hens to their cages, etc).

Besides the rather organizational and technological perspectives, we find that the involvement of the population has to be significantly improved and extended. This does not only mean the notification and instruction of the general public, but the active integration of every single citizen (e.g., by bidirectional communication). The inclusion of the population can be quite effective, as it was, for example, demonstrated in Thailand in 2004 during the avian flu outbreak [14].

Further points are education, availability of communication media, and the conveying of responsibility. This especially includes the integration of existing wireless communication infrastructures that mobile communication, information, and notification of the general public (possibly in a particular area) about an impending disaster (e.g., a pandemic) and possible remedies (e.g., Short Message Service (SMS)).

We have initiated a multi-disciplinary project with inputs from the (research) areas of healthcare, ICT, and management to study the regulatory issues for the Asian-pacific region with the help of industry.

The goal is to efficiently introduce and coordinate health systems in all countries (national level) that cooperate very closely (international level). This is to be ensured with a tight and reliable communication and information exchange infrastructure as the backbone of such a network. In addition to this, both the development of and the agreement on global standards have to be realized. We are in the process of setting up the *Asia-Pacific Ubiquitous Healthcare Research Centre* (APuHC) at UNSW Asia in Singapore[20] using a global network management centre to demonstrate the interoperability issues.

We are also working as part of the International u-Health Initiative[21]. This initiative involves a number of countries in the Asian-pacific region and aims at reusing existing system management solutions from other business sectors (e.g., telecommunications) and applying them to the service management in E-Health, hopefully offering adequate and sufficient support for disease control to all countries in the long run: diseases do not know borders, and so must we.

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