Nipah outbreak in Kerala – A network-based study

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Abstract. Nipah virus spreads from human to human at a fast pace by contact. It has been realized that very close contact for a long period or direct exposure to excretions of diseased can cause the spread of the virus from one person to another. So avoiding contact with infected is very crucial in the control and eradication of the disease. Getting information about infection in the early stage is an important factor in the planning of isolation of infected and suspected. The contact pattern of humans in society makes a network of individuals. Dynamics of social networks have become a focal point in the mathematical study of the spread of disease in recent years. In normal situations, an individual comes in contact with others due to many reasons. We have contact with our family members, relatives, and friends. We come in contact with others by chance when we are in public places. In the paper, we analyze the recent Nipah outbreak in Kerala and explain the dynamics based on social network analysis. The paper aims to bring into light the importance of a network-based analysis of the infected immediately after the outbreak of the disease. The contact pattern must be closely analyzed to decide who should be quarantined and observed.

1. Introduction
The first outbreak of Nipah was reported in Malaysia and Singapore from September 1998 to May 1999. The virus was called ‘Nipah’ in the name of the village in Malaysia, where the virus was first identified in a patient. More than 276 cases of acute encephalitis and 105 deaths were reported in this outbreak [8]. It is strongly argued that infection of humans occurred from infected pigs. These pigs were probably infected from the Malaysian Island flying foxes [1, 2]. The mortality rate in the outbreak was 38% approximately.

A total of 11 outbreaks were recorded in Bangladesh between 2001 and 2008 with an average mortality rate of 80% and in some cases, it reached up to 100%. In India, the disease outbreak occurred at Siliguri in 2001 and Nadia in 2007, both in West Bengal. These places are very near to Bangladesh [3,4,5,6,7,8,12]. It is strongly argued that humans in India contracted the disease due to the consumption of bat-eaten fruits [9]. It is believed that infected horses are the reason for the outbreak reported in the Philippines in the year 2014 [10]. The incubation period of NiV in humans ranges from 4 days to 2 months, with more than 90% occurring at 2 weeks or less [4].

In recent years Kerala, a southern state of India has caught the attention of other nations due to the attack of the deadly virus such as NiV and CoV. Kerala has attained 100% literacy and has a well-developed network of the health care system. People of Kerala widely travel to other countries to study, as tourists and as job seekers. Both the public sector and the private sector take part equally in
the healthcare system in the state. The first outbreak of NiV was reported in Kerala in the year 2018 in Kozhikode district.

During the period from 2nd May to 29th May 2018, 23 cases were identified. Out of these 18 cases were confirmed in the laboratory. The lineage of the NiV was similar to that of the lineage of the outbreak in Bangladesh. The incubation period ranges from 6 days to 14 days (average 9.5 days). 87% (20 patients) of them showed respiratory symptoms and 91% of the infected died [11, 14].

2. Kermack – McKendrick Model for Nipah Virus Spread.

The spread and dynamics of Nipah have become the subject of study in several research papers since 1998. In some of these papers, the authors attempt to analyze the dynamics based on the popular Kermack – McKendrick models (also called the compartmental models). The basic SIR model is used to study the dynamics of the Nipah (Niv) virus spread in Bangladesh. The basis of the model is a set of ordinary differential equations that describe the transfer of members from one compartment to another. The system of equations is solved to analyze the dynamics of the disease.

In the SIR model the whole population is divided into three compartments S(t), I(t), and R(t). The compartments S(t), I(t), and R(t) respectively represent the number of susceptible, infected, and recovered individuals in the whole population (denoted by N(t)). So we have N(t) = S(t)+I(t)+R(t). Two types of models are suggested by Haider Ali Biswas in a paper to study the NiV outbreak in Bangladesh [13]. The first model is used to study the disease without vital dynamics over a short period (less than one year). It is represented by the set of equations (1) given below.

\[
\begin{align*}
S'(t) &= -\beta \frac{S(t)I(t)}{N} \\
I'(t) &= \beta \frac{S(t)I(t)}{N} - \alpha I(t) - \gamma I(t) \\
R'(t) &= \gamma I(t)
\end{align*}
\] (1)

With the boundary conditions, \( S(0) = S_0 \geq 0, I(0) = I_0 \geq 0, R(0) = R_0 \geq 0. \)

But the second model represented by the set of equations (2) is to study the disease for a longer period. So the renewal of susceptibles by births or recovery from temporary immunity is also taken into account.

\[
\begin{align*}
S'(t) &= \mu N - \mu S(t) - \beta \frac{S(t)I(t)}{N} \\
I'(t) &= \beta \frac{S(t)I(t)}{N} - (\alpha + \gamma + \mu) I(t) \\
R'(t) &= \gamma I(t) - \mu R(t)
\end{align*}
\] (2)

With the boundary conditions, \( S(0) = S_0 \geq 0, I(0) = I_0 \geq 0, R(0) = R_0 \geq 0. \)

In this model \( \beta \) is the contact rate, \( \alpha \) is the disease-induced death rate, \( \mu \) is the birth rate and \( \gamma \) is the recovery coefficient. These models are used to analyze the data set (Table 1) of the outbreak in Bangladesh for the period from 2001 to 2012. The most peculiar thing about the outbreak in Bangladesh is that it continued over a long period.
Table 1. Nipah outbreak of Bangladesh from 2001 to 2012 [13]

| Outbreak (Years) | Number of Infected | Number of deaths | Percentage |
|------------------|--------------------|------------------|------------|
| 2001             | 13                 | 9                | 69         |
| 2002             | 0                  | 0                | 0          |
| 2003             | 12                 | 8                | 67         |
| 2004             | 67                 | 50               | 75         |
| 2005             | 12                 | 11               | 92         |
| 2006             | 0                  | 0                | 0          |
| 2007             | 20                 | 13               | 65         |
| 2008             | 10                 | 9                | 90         |
| 2009             | 4                  | 1                | 25         |
| 2010             | 17                 | 15               | 80         |
| 2011             | 24                 | 24               | 100        |
| 2012             | 6                  | 6                | 100        |
| Total            | 185                | 145              | 79         |

This model was further modified by Jakia Sultana by incorporating some optimal control strategies [15]. The optimal control technique is used to analyze the model dynamics by including two control strategies. Creating awareness is one strategy and treatment is the other.

What we can see from the data and the analysis of the Bangladesh case is that the control of the disease is inefficient and it recurs in equal periods. We compare this situation with the outbreak of the disease in Kerala. We examine which method is effective to control the spread of disease completely.

3. NiV Outbreak in Kerala and analysis using Network Models.

In the report, Govindakarnavar Arunkumar et al. [14] describe the nature of the first outbreak in Kerala. For completing the study, they visited the places related to each patient and conducted interviews of all the people who can give information about the patients. All the possible contacts of the patients were investigated.

The index case in the outbreak developed symptoms of the disease on 2nd May 2018. On 3rd May, he was rushed to the hospital, where he was treated for two days without knowing the nature of the disease. On May 5, he was transferred to another hospital in a vehicle. During this period his father was in close contact with him. On the evening of the same day, he died in the second hospital. Of the 22 additional NVD cases identified, 10 cases were from the contacts of the index case in the first hospital, and 10 were from the contacts of the index case in the second hospital. The first set of infected contains the relatives of the index case, patients who came in contact with the index case, and their relatives. The second set of primary infection cases contains patients in the second hospital, their companions, or caregivers who came in close contact with the index case when he was in the second hospital. Three remaining cases were secondary infections. Using this information available in [14] a network of the disease transmission is drawn, which is given in Figure 1.
Figure 1: The contact network of the first Niv spread in Kerala

In the network, the node with number 1 is the index case. All red coloured nodes represent the infected by contact from the index case while in the first hospital and the orange-coloured nodes represent the infected cases by contact with the first person, while in the second hospital. Brown coloured nodes represent secondary infected cases.

Disease control measures started immediately after the confirmation of the Niv virus. All the people who have shown symptoms of the disease were admitted in isolation-ward. Information about the nature of the disease and the methods to reduce the chance of the transmission from individual to the individual was given to the public through mass media. The people of Kerala know very well how to respond to such precautionary measures. They can break all contact with the people suspected to have the disease. It is the complete isolation of all the diseased people and those who suspected to have contact with the infected helped the health care agencies to control the disease completely.

A new case of Niv infection was detected in a 23-year-old student again on 4 June 2019 in Kochi, in Eranakulam district in Kerala. The Health Department of Kerala had gained experience and developed a system of treatment by the time the second Nipah patient was admitted to the hospital. The patient was a student in a private college in Idukki District. Just before admitted to the hospital he visited a training camp in Thrissur district. Immediately the people in three districts were scanned to find all possible contacts he had in the immediate past. All the suspected contact cases were kept under strict monitoring. All immediate contacts with the infected were moved to isolation until a specified time has elapsed. In contrast with the index case of disease spread in 2018, this patient was not coughing uncontrollably. This might also have reduced the possibility of infection of others. Finally, the authorities managed to control the disease without reporting any secondary case of infection. From the two cases in Kerala, it is evident that early detection of the viral attack, identification of the actual virus, and timely complete quarantining and monitoring system can very effectively control virus attacks.

This study is relevant in the circumstances of the great pandemic COVID-19 [16]. The control of the disease in the initial days of its appearance in the world was extremely weak. It caused the transmission of the disease in almost all countries in the world. It grabbed the life of lakhs of innocent people and gave unlimited miseries to millions of poor. It also dragged all the countries through
unexplainable hardship and chaos. This unjustifiable incident could be easily avoided by applying social network techniques along with disease prevention strategies such as quarantining, isolation, social distancing, etc. This study sheds light on how Kerala attained during the days of the Nipah outbreak.

4. Conclusion

In this paper, we have compared the network analysis method with the compartmental model method for its effectiveness in controlling the spreading of viral diseases. Application of the methods of controlling contacts in social networks is extremely effective compared to the application of the compartmental type models and optimal control techniques. In the situation of the outbreak of fatalistic viral diseases, we cannot wait to recur it, again and again, to collect data to analyze it to arrive at conclusions. Simple methods of quarantining can create a magical effect on the control of the disease.

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