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Estimating traffic change in accidental regional node failure for Asia pacific IP networks

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ABSTRACT

Connectivity seems to be one of the significant features of today's life. People rely on their technology in almost every aspect of their daily living. They also depend on this technology to be accessible anytime and anywhere. It is true that technology has touched every feature of today's life. However, it is the networks that allowed this touch to reach almost everyone, regardless of who or where they are. Disasters stand for the oldest challenges that ever faced humanity. Since societies are extremely dependent on the technology, it is imperative to face the challenge in terms of technological communication systems. In this paper, the Accidental Disaster Network Impact Model is used to study the impact of a regional computer network failure triggered by an accidental disaster on the surviving network. The main aim is to study the percentage of change in traffic and lost traffic in node failure scenarios. This research estimates the change in traffic in cases of single node failure and double node failure. Also, it addresses the case of partial node failure in which only part of the communication ability is lost. The research also generates a simplified network map that represents the regional network of Asia Pacific.

Keywords: Modeling network failure, Disaster mitigation, Regional network failure, Sustainable networks, Survivable networks

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1. Introduction

Computer Networks' failure is being progressively important and costly, due to the large dependence on them in everyday life, thus increasing the importance of insuring a highly survivable network. Disasters are highly unavoidable events and even resilient and well-managed networks can still be affected by a failure in the regional network that is caused by a geographically related failure like an accidental disaster. So, it is important to plan for such events.

Moreover, the importance of networks and their role is enhanced considerably during disasters. This is because of disaster management highly depends on networks in aspects of coordination, notification, evacuation instruction, victim locating and logistics. Moreover, the individuals' ability to use IT technologies can affect their resilience to disasters [1]. Although the impact can differ from one disaster to another depending on impact factors, but there is no way to out run disasters. The only way is to minimize the damage by planning, since preparedness is the secret for saving the people and the economy [2].Therefore, it is very important to consider networks as part of the vital infrastructures for the purpose of disaster planning in all its stages.

Networks survivability is even more important in surviving networks' parts, those are the parts out of the disaster range. Because the network failure will change the topology, therefore the network traffic will also change. Some of the network traffic would be lost. But, the rest of the network will continue to function. This will put more traffic pressure on the surviving part and this extra traffic could cause network congestion that may cause more failure in other parts of the network. If regional networks fail, in parts of the region out of the disasters impact, then the disaster has escalated to additional accidental disasters. The basis behind this is because network failure on such scale will disturb the community living, thus is a disaster on its own [3] [4].

In addressing disasters, researchers address them from three areas that are relevant to time line of the disaster, which are; pre-disaster, during disaster (disaster management) and post-disaster studies. This paper focuses on pre-disaster research, which covers monitoring disasters as well as modeling and simulation. Modeling and simulation are used in studying disasters like other fields of studies where the events have high factor of danger or where study circumstances are not easily repeatable [5] .

Although through disaster literature, there is no one standalone definition of disasters. The disasters' researchers seem to have more argument than agreement [6]. The doubtless fact about disasters, which no one can argue with, is the damage they can cause. Regardless of type or magnitude, disasters can cause great damage. In this context, disasters are viewed as the distress or distribution in the society way of living caused by a trigger event. It is out of the ordinary behavior caused by some emergency events.

This leads to the conclusion that events like earthquakes, terrorist attacks and factory fires are not the real disasters, but rather triggers. The actual disaster is the suffering and distress caused by those events. Similarly, there are a number of disasters' classifications. This research adopts the classification of disasters as being accidental and deliberate [7]. Another way of looking at disasters, which is also based on viewing disasters as the unwelcomed change, is viewing them in the light of its impact range. If a disaster affects a relatively small area, then it is a local disaster. If that impact spread further to affect an entire region, then this makes it a regional disaster.

Disaster escalation only complicates disaster management, and put even more people in the disaster zone. It also increases disaster's impact and cost, as well as complicating recovery process. Therefore, it is very important to focus on survivability of the network components out of the disasters range due to the very important role that it has and because the disaster seriously jeopardizes the survivability.

Some works have been done in the area of disaster impact on computer networks based on addressing network topological failure as a disaster impact [8-10]. However, the work done by them does not address the change in network caused by the failure, nor do any other studies for addressing the change in surviving network traffic, which is caused by a disaster triggered topological failure. This research showcases the application of the Accidental Disaster Network Impact Model (ADNIM), which was given in previous works in [11-12] on the disaster triggered failure scenarios in Asia Pacific. It shows that the model is applicable for scenarios that have taken place and those that are theoretical. Therefore, it is usable for survivable networks' planning.

2. Methodology

In order to achieve the goals of the research, a multi-phase methodology was adopted. This paper's methodology is shown in Figure 1. The process involves five phases as the figure suggests. Those phases aim to find the impact of different types of regional node failure, which is triggered by an accidental disaster in the Asia Pacific region on the surviving networks. In other works, the change in traffic in the surviving network after an accidental disaster originated failure has disabled node(s) in the region.

This can help in shading light on the expected outcome of such disasters on regional networks. On the other hand, it can be used as a design strategy for sustainable and survivable networks in the region. Thus, it improves infrastructure sustainability and community preparedness.

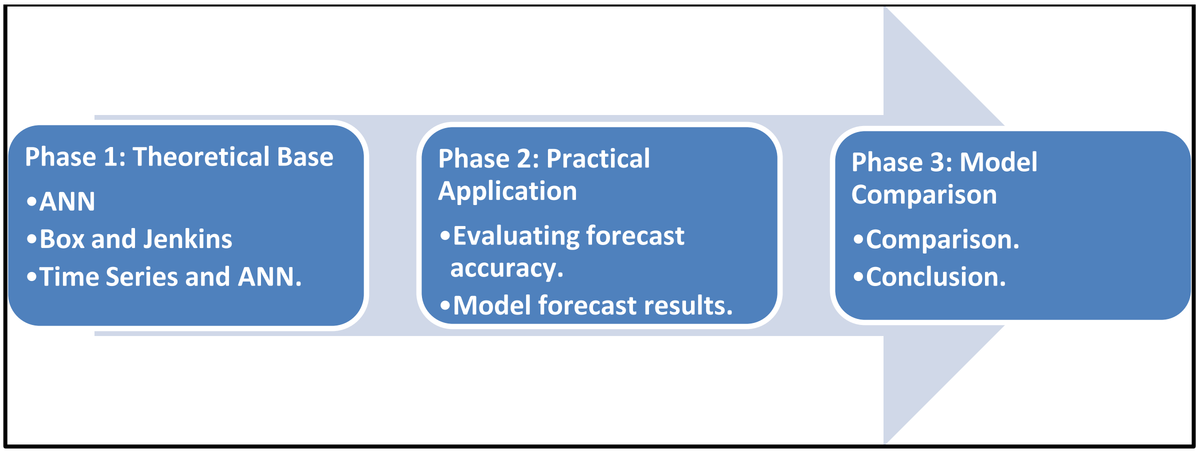

Figure 1. Methodology

2.1 Phase 1

In this phase, the different possible node failure types are detailed along with their associated disaster triggers. Based on previous disasters in the region, the possibilities of such events' impact on network regional nodes. Three types of node failure were identified in the phase:

- Single node failure.
- Double node failure.
- Partial node failure.

Single and double node failures are a commune case. The failure can be in the first case due to nodes in the geographical disaster impact zone. Meanwhile, a double node failure can occur when dealing with wide impact area disasters. In both cases, the failure could be existing, but is not insolently caused by damage to the node's infrastructure.

- For the third type of node failure named as partial node failure, this type could happen with scenarios where the node's infrastructure is not damaged, but other elements has rendered the node as un-functional, such as node failure due to power outage. Those types of failures are happening more often with the increase of the dependence on technology, thus causing more complex and accumulated disasters with complex triggers leading to more triggers such as technological triggers.

2.2. Phase 2

In this phase, scenarios for the identified types of failure are selected, the selection is based on the nature of the region and the history of disasters that the region has faced. From studying the regions vulnerabilities and highest impact disaster triggers [13], the three disasters with the highest impact were selected. Those disasters are firstly the floods in the Asia Pacific region. Floods are one of the major disasters in terms of its impact and damage. They are often in the region caused by rain. Therefore, the impact area depends on the impact area and center rather than following the shape and directionality of the river. Since it is not necessarily confined with the river's catchment basin for this type of trigger, a double node failure was selected. Therefore, the case of a two nodes filing in the southern part of Thailand due to flood is selected.

Secondly, for the case of node failure 2, specific scenarios are selected. The first one is single node failure due to flood, thus once again the case of node failure due to flood in southern Thailand is selected. The first scenario has chosen as flood is the highest impact standalone disaster trigger in the region, as well as to provide the chance to analyze the relationship between single and double nodes with similar conditions. A second scenario is also selected for a complex disaster trigger with an Earthquake and its escalation. This scenario is the case of a single node failure due to an Earthquake and Tsunami in Medan.

Lastly, the partial node failure case has investigated. In this case, a scenario covers the case of a complex disaster trigger with a technological trigger to follow the first trigger. For this scenario, the Great East Japan (Tohoku 2011) disaster, when an Earthquake led to a Tsunami that led to nuclear power plant meltdown in Fukushima. This caused a power outage and 40 % power loss in Tokyo. The scenario covered in this paper is the partial node failure in Tokyo due to power outage only. The rest of the disaster impact was covered by earlier publication [12].

2.3. Phase 3

The Accidental Disaster Network Impact Model (ADNIM) is used to run the selected scenarios. The model was introduced in earlier publication, and was validated using traffic data related to the Tohoku 2011 disaster. In order to run the simulation for the Asia Pacific region, a few preprocessing steps need to be performed.

First a regional network map needs to be generated that would include combining local network maps, as well as comparing and integrating maps from different network providers. Moreover, adjacency matrix that describes the network connectivity rules needs to be calculated. The same matrix was later used to calculate the basic amount of traffic defined by “t”. In order to calculate the real traffic, the degree of homogeneity of the network must be changed and a value of demand /supply intensity must be assigned to each node.

The route between each two nodes is calculated to find the amount of traffic generated by the supply and demand between each two nodes, and the links carrying this traffic, thus finding the amount of traffic passing through each link. There is a direct link between the two nodes on the map as in the link L1 connecting N1and N2. There is no direct link exists like the case between N1 and N28. In this case, there is not only one link connecting the two nodes, but a set of links. The set of links is L34, L29, L20 and L3. This set is found based on the routing algorithm with SPF in this case because it is an IP network.

The same process is applied to all nodes. As a result, the links is connecting each two nodes for each node that is defined. All these details are presented in a form on a table. The resulting table is a 29 by 29 table, which represents the adjacency. The contents of each cell represent the links connecting the node from the column with the node from the row. In this way, it is very easy to find a way for each two nodes that are connected.

In order to assign the amount of demand intensity for each node, community information such as the population of each state and the percentage of communication technology penetration of the community in that state have used. The result is a list of the impact coefficient for each node on the network as in the intensity of supply / demand for each node, multiplying the homogeneous supply, demand by this coefficient yields the actual supply, and demand of the network that can be used by the model to calculate network traffic in reference to unit of traffic such as “t” of traffic. Thus, it is useful to provide normal network traffic based on “t” notation.

2.4. Phase 4

In this phase, the change in network traffic because of the failure is calculated. The model requires a predefined coordination node. It also requires the distance of each node from the coordination node, and this information is stored in the distance matrix. Then, the change in traffic is calculated for each scenario. Firstly, the damaged nodes are decided for the scenario. This is done by calculating distance from the impact center for each scenario trigger. The affected nodes are then removed from the network, thus resulting in a new network. Then, the same process has used to calculate the normal network traffic to be applied to the new post failure network. The difference between the normal traffic and post failure traffic is the change in traffic.

The proposed model differs from other models [8] so that the model does not assume that all nodes in the impact area will fail by default. Moreover, the option of partial node failure is addressed and the model is able to calculate such scenarios. The capability of addressing partial failure scenarios for node is in highly significance to cope with complex disaster triggers, such as power outage that occurs after an initial triggers.

2.5. Phase 5

Based on the results from the traffic change, analysis is done in this phase, thus providing key indicators on the expected impact of a specific regional failure scenario on the network in general and stands alone parts of the network. Based on that, an action plan can be advised for each scenario. Moreover, cases of scenarios that have not taken place can be addressed. Studying scenarios for networks during planning phase are presented to find required infra structure for a highly survivable networks from early design stages.

3. Results

In this section, an overview of the results for each node failure scenario is presented. In order to put the mentioned results in context, the results from the first phase is shown in Figure 2. It shows the generated network map for the area under research which is Asia Pacific region. After acquiring the maps, they are compared against each other and only when nodes and links are coherent with other used maps. The same process is applied to maps provided by local service providers in Malaysia. The same rules for simplifying the nodes are applied with the exception that the distance limit for merging two nodes is 100 km because this map stands for a region, not a single country. For this way, the map simplifying rules are:

1. The distance between each two nodes on the map was determined.
2. All nodes that have a high-speed link and are less than 100 km in distance of each other were merged.
3. The center node C according to importance, links and position on the map, was decided.
4. The distances of external nodes from C were found.

In Figure 2, the resulting map represents the region, and the adjacency matrix is generated as well as the distance matrix and the supply/demand matrix. The list of nodes in the map and their corresponding cities are shown in Table 1. Although Figure 2 does not show the labels of links connecting the nodes in the map, the full list of links is provided in Table 2. Consequently, the local and regional map is generated along with the network information needed for calculating the basic traffic such as the adjacency matrix. Moreover, the distance between each node and the coordination node (N1) is represented in the distance matrix. This is crucial in calculating the probability of survivability based on the distance from coordination node and the distance from the disaster impact zone.

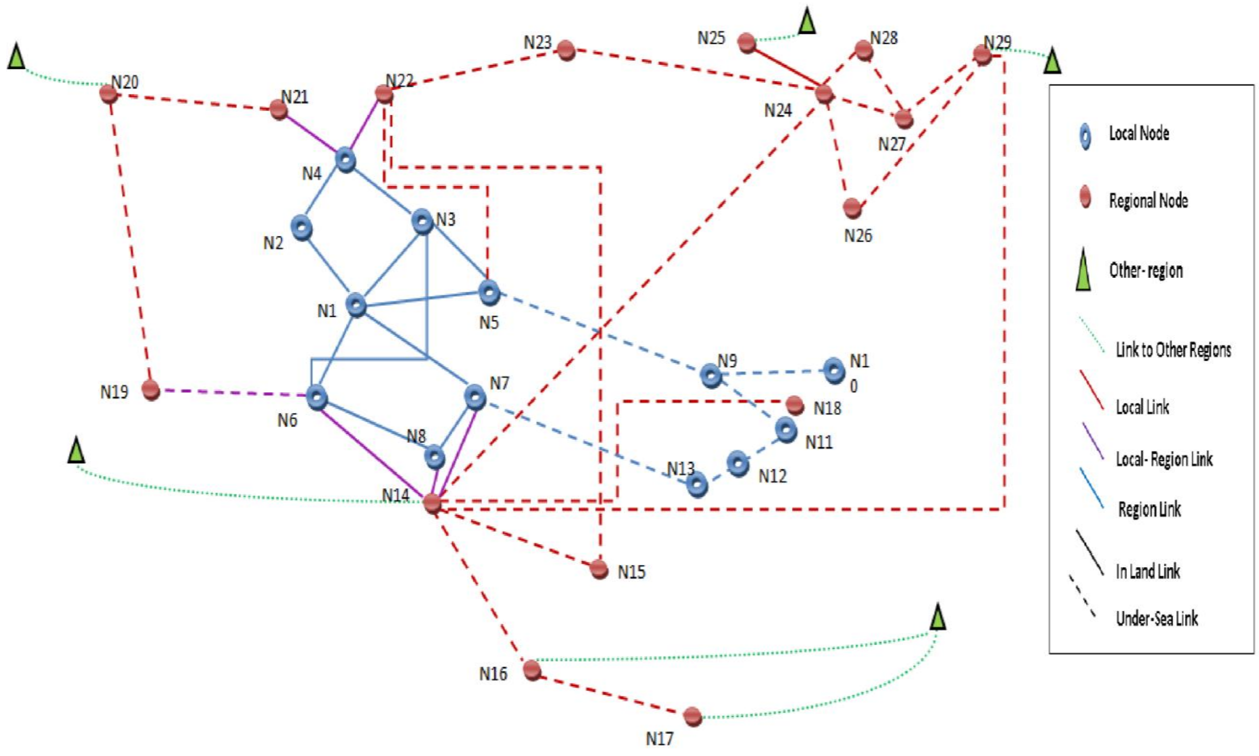

Figure 2. Generated Regional Network Map

Table 1 Network Nodes and Corresponding Cities

Node-Local	City	Node-Regional	City
N1	Kuala Lumpur	N14	Singapore
N2	Ipoh	N15	Jakarta
N3	Penang	N16	Sydney
N4	Kota Baharu	N17	Auckland
N5	Kuantan	N18	Bandar Sri Begawan
N6	Melaka	N19	Medan
N7	Mersing	N20	Bangalore
N8	Johor Baharu	N21	Satun
N9	Labuan	N22	Sonkhl
N10	Kota Kinabalu	N23	Shenzhen
N11	Miri	N24	Shanghai
N12	Bintulu	N25	Hong Kong
N13	Kuching	N26	Manila
		N27	Taipei
		N28	Seoul
		N29	Tokyo

Table 2. Sample Links and their Connected Nodes

Link	1st Node	2nd Node
L1	N1	N2
L2	N1	N3
L3	N1	N6
L4	N1	N7
L5	N1	N5
L6	N2	N4
L7	N3	N4
L8	N3	N5
L9	N3	N6
L10	N6	N8
L11	N8	N7
L12	N5	N9
L13	N7	N13
……	……	………
L38	N27	N28
L39	N27	N29
L40	N16	N17
L38	N27	N28
L39	N27	N29
L40	N16	N17
L41	N19	N20
L42	N14	N18
L43	N2	N19

Following the method described in Section 2, this method is used to calculate the demand intensity indicator. The results show a huge diversity due to difference in population density and technology penetration between rural and urban areas in the region as well as the difference between countries' infrastructure in the region. For instance, diversity in Malaysia is the case of intensity in N1 representing Kuala Lumpur area with indicator of 18, thus resulting with 18 times the basic supply/demand from a homogeneous network. For N9 with indicator of 0.2, this node represents Labuan. Based on the map, the basic traffic has calculated with change of traffic for the following scenarios.

3.1. Scenario 1: Node Failure

This scenario addresses the case of a node failure, which is not combined with a link failure. A natural trigger such as an earthquake can trigger such scenario or a technological trigger such as a power outage can trigger it. In this scenario, it is assumed that one of the Indonesia's nodes would fail due to a natural trigger since the area suffers such natural events regularly.

3.1.1. Scenario 1-A N19 Failure

When N19 fails without any of its links failing, all traffics originated from this node and that ends in it are to be lost. Thus, the node will have no supply or demand. Actually, the node will no longer be part of the network until it works again. This scenario represents a failure in Medan.

The amount of traffic before the node failure is 16592t. After performing the process of calculating the change in traffic to find the lost traffic, the amount of traffic after the failure becomes 15904t. This means that the lost traffic is 688t that makes the lost traffic rate of 4.1465 percent.

3.1.2. Scenario 1-B N15 Failure

Similar to the previous case, when N15 fails, representing Jakarta, all traffics from this node and to it will be lost. Just as in Scenario 1-A, the node is no longer part of the network. This case is very similar to the previous case. The only difference is the amount of lost traffic, because it depends on the original amount of traffic based on its own node. The same process is applied in this case and the new traffic is 16268t. Therefore, the lost traffic is 324t. This lead to a 1.9 percent of traffic loss.

3.2. Scenario 2: Double Node Failure

Once again, in the case of node or multiple nodes failing with their links are still intact, this would mean a trigger that does not damage the components, but rather disturb the node functionality for other reason. As in the previous scenario, that reason could be because of flood, power outage or any other trigger that results in similar effects.

3.2.1. Scenario 2- N21and N22 Fail

Here, the choice is on a Thailand node failure for the same reasons as in the first scenario. The only difference is that instead of one node failing, this time both N21 and N22 fail at the same time. As in the previous scenario, the original traffic is 16592t. The new traffic after both nodes failing is 15160t. So, in the same way, the traffic lost is 1432t, and the percentage of traffic lost is 8.63 percent.

3.3. Scenario 3: Partial Node Failure

In this scenario, a node would lose only part of its supply and demand and therefore only part of its traffic. This could be the case when a node is gateway to a local network that is not visible to the other nodes in the regional network. The nodes of this network can access the regional network only through this gateway node. Therefore, if part of that local network fails, the gateway node will lose some of its supply and demand. This is because only a part of that supply and demand really belongs to the node. In fact, it is inherited from the local network, and it connects to the regional network. The other option is if the node hardware does not fall, but stop working due to other technological trigger such as power outage, therefore the traffic would be lost because of electric failure.

3.3.1. Scenario 3- N29 partial Fail

As for this case, the scenario of the event from the Great East Japan (Tohoku 2011) disaster is selected, because it is a good example of disaster escalation. In this scenario, Tokyo lost 40% of its electric power due to electric rationing and scheduled electric cuts. The original network traffic is the same to other scenarios, since it is the same network. The change in traffic is calculated and it shows 15920t. This means that the network lost 402t that is 4.05 percent of its original traffic.

3.4. Failure Scenarios Summery

From studying the various node failures, it is shown that although the general aspect, there is no traffic supplied or demanded by the failing node. However, with the escalation of disasters, it is shown that a partial failure is possible, Table 3 shows the finding of the research in terms of change in traffic, or traffic loss, denoted by "t" as well as in terms of percentage of traffic.

Table 3. Traffic Change from 3 Failure Types

Failure Type	Node	Lost Traffic by t	Lost Traffic %
Single Node	N19	688t	4.1465
Single Node	N15	324t	1.9
Double Node	N21 & N22	1432t	8.63
Partial Node	N29	402t	4.05

4. Conclusion

The dependence on technology might be one of the trends on the era. There is no argument that it has enabled a significant amount of services and made life considerably more diverse as well as bringing the whole world closer. At the same time, this has increased the human's way of life vulnerability to disasters and crises. Those events are a diversion from the society's norm representing a challenge and at the main time evolving disasters to include new types of technological disaster triggers. Moreover, introducing accumulated disasters with one trigger can lead to another.

The paper shows the cases of node failure. Special attention need to be given to partial node failure where only part of the node fails. This has not been addressed before, but it is a necessity, because a technological trigger can cause the node to be partially functioned. Moreover, addressing the double node failure is an important observation when nodes fail at the same time. With their links still intact, the lost traffic is equal to the combination of traffic lost if each one fails separately. But this is not the only fact. If both N22 and N21 fail at the same time, then there is no access to the nodes through the regional network. This means that resources in this part of the network are not accessible through the network itself thus disabling end-to-end connection. In such cases, the impact of the failure will be passed to other networks out of the region. Therefore, this stands for the failure a global network issue that could affect other regions.

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