Flood Analysis and Prediction Support based on UML and Mobile Petri Net Specification and Verification

Sher Afzal Khan, Rao Sohail Iqbal, Nazir Ahmad Zafar and Farooq Ahmad

Abstract—**Flood is one of catastrophic disaster that directly and indirectly affects the living style of people in the critical region. It is proved that there is no mechanism to avoid flood but only a prediction, which can secure the inhabitants of inundation areas. To predict flood, different countries adopt different techniques like SPH (Smooth Particle Hydrodynamics), Hydrograph, FRICS (The Foundation of River Basin Integrated Communications), and DMS (Disaster Management Support) etc. However, it is observed that these techniques do not take an advantage of upcoming development to predict the flood. To cater it, in this research a new model is proposed based on Mobile Agent technology. Usually the inundation area is distributed over thousands of kilometers, so far communication among agents we prefer to use VSAT (Very Small Aperture Terminal). We categorized the mobile agents according to responsibility like server and client mobile agents. Client is responsible for discharge calculations, whereas, the server calculate an inundation area to predict based on the discharge received from the client and historical records. The model is developed using UML activity diagram. Finally, the model is specified using mobile agent Petri net and then verified by reachibility graph.**

Index Terms—**Flood Prediction; Mobile Agents; UML Activity Diagram; VSAT.**

I. Introduction

FLOOD is purely a threat for human activities inhabit in critical regions [2]. Many countries faced terrible flood that remained as fear for generations. Most of flood hazards occurrences increased in a lot of countries like India [11], Malaysia [7], China[15], Japan [16], Turkey [5], Bulgaria [12], Pakistan and Bangladesh [1]. The world faced this potent danger which claimed 20,000 lives and 75millions people in every year [1]. Pakistan is one of the countries that faced a catastrophic disaster of flood in her history which caused human, economic and environmental issues. Flood occurred in Pakistan in August 2010, it severely affected almost the whole country, brought the loss of more than 3,000 precious lives, and displaced 10 million people during this period. This flood inundated approximately 130 million hectors of croplands [1]. There are many causes of creation the flood situation: heavy rains over a small area, twists of air over water, high tides, tsunamis in sea, failure of reservoir, and unexpected melting of snow due to warm conditions [11], [15], [16]. Similarly passage of time streaming channels of rivers also lose their capacity of discharge due to sedimentation, as a result a flood situation [14]. Floods mostly occur in mountain areas, when absorption of water is low and overflow is not controllable by river channels. Floods are natural disaster and inevitable but losses can be minimized with well managed mechanism. To manage the flood and to minimize the impacts of disaster, techniques of prediction is a great challenge in countries facing it regularly.

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The countries like Netherland, India, China, Malaysia, and Pakistan etc, are working for appropriate prediction to rescue their people. If a flood is forecasted at a time, then a lot of casualties can be avoided. In forecasting, inundation area needs to be calculated for evacuating the inhabitant of critical region. For this many of techniques are developed in different countries to predict the flood in time for taking appropriate decisions to counter this potent danger [3], [7], [8]. First and most famous technique adopted is Hydrograph which plot a graph of discharge. In the graph, discharge is represented on y-axis with relative to time on x-axis. Unsteady Flow River Model is also used to predict the flood, based on computer system that take some parameters like input flow of river, capacity of river and discharge for flood prediction[3]. Some simulations based solutions [2] are developed like SPH (Smooth Particle Hydrodynamics) and ANFAS [9]. SPH used MAYA, GIS (Geographical Information System), DEM (Digital Elevation Model) and remote sensing image to model inundation area [7], [13]. ANFAS used simulation based software for estimating inundation area [15]. FRICS (The Foundation of River Basin Integrated Communications) is a web-based solution with 700 different points all over Japan to calculate river flood and apprise the people through internet [16]. A project DMS (Disaster Management Support) initiated by Government of India (GOI) and United States Agency for International Development (USAID) to rescue the people of India from a flood danger. DMS emphasis on flood forecasting and create map of inundation area [11]. A project implemented in Turkey and Bulgaria has three phases, one for sharing information and rest phases for prediction [12]. Both countries are connected by a permanent and reliable medium with four stations established in Bulgaria for measuring the discharge and continuously appraising both countries by GSM. From the above discussion it reveals that serious efforts have been taken to reduce human and economic losses, however, it is not achieved with appropriate success [8]. Flood monitoring and prediction systems are critical and crucial and delay in decision or incorrect decision

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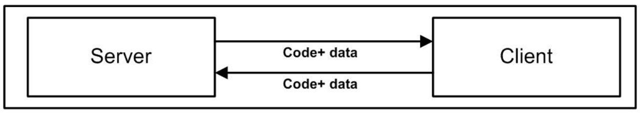

Fig. 1. Server and Client Mobile Agent

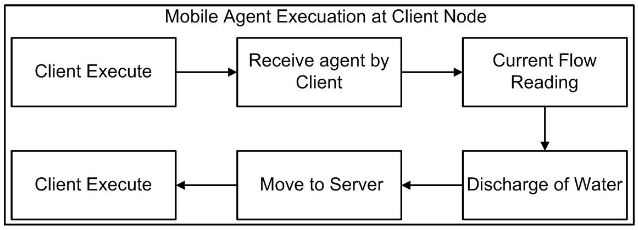

Fig. 2. Sub Activity Diagram of Client

may make lives in danger. It is seriously required to develop a system that can make correct decision at appropriate time before the flood occurred. In existing techniques data is transferred from node to node for decision. In some techniques image data is transferred that need a high bandwidth [7], [11], [15]. Since the model is distributed in nature and computational, we proposed a mobile agent approach to develop the flood measurement and prediction in this research. Mobile Agent is a new version of agent that transfers its code from one computer to another in spite of data, [13]. It is faster in execution as compared to systems transferring data [4], [9]. The agents in mobile agent systems can migrate to connected (local) as well as disconnected (remote) agent for execution [9]. It has autonomous ability that support its disconnected execution without any interruption on connection lost and communicates on connection re-establishing. The importance of the mobile agent technology can be seen from its application in different areas [4]. In our model we divide the model in two part server and client agents as shown in the Fig.1. Server is used to initiate the request to a particular client about its discharge uses mobile agent. The client read the discharge at client and updates the server through a mobile agent to server. Finally, the server agent uses the discharge at client and makes the prediction of flood with inundation area using historical data of flood about a particular region.

In the system we propose VSAT (Very Small Aperture Terminal) system for communication among mobile agents due to its affective performance in any situation of natural disaster. The system is modeled using graphical notations of UML (Unified Modeling Language) i.e., the activity diagram. UML is a graphical language composed of different notation, help in designing and representing the system. Whereas, the activity diagram is used to describe procedural logic, business process and work flow. It is very close to flowcharts except parallel behavior supported in activity diagram [6]. The use of activity diagram increases in capturing a lot of situations. For representing the distributed computing, activity diagram can be used due to its parallel behavior. Further for the specification we use mobile Petri net [20] and its verification is performed by the reachibility tree. Petri net (PN) is one of the formal methods used for the specification and verification of concurrent and distributed systems [19], [21]. PN theory has a sound mathematical basis including linear algebra, graph theory and discrete mathematics. Therefore, net analysis and verification is possible. Many properties can be decided by theoretical means. Mobile Petri net is the extension of the Petri net [22]. Further, the connected mobile Petri net is a Petri net. Hence all the verification properties of PN can be applied to the MPN. The organization of the paper is as follows: In section 2, model is developed using activity diagram. In section 3, specification and verification is presented. Finally, conclusion is discussed in section 4.

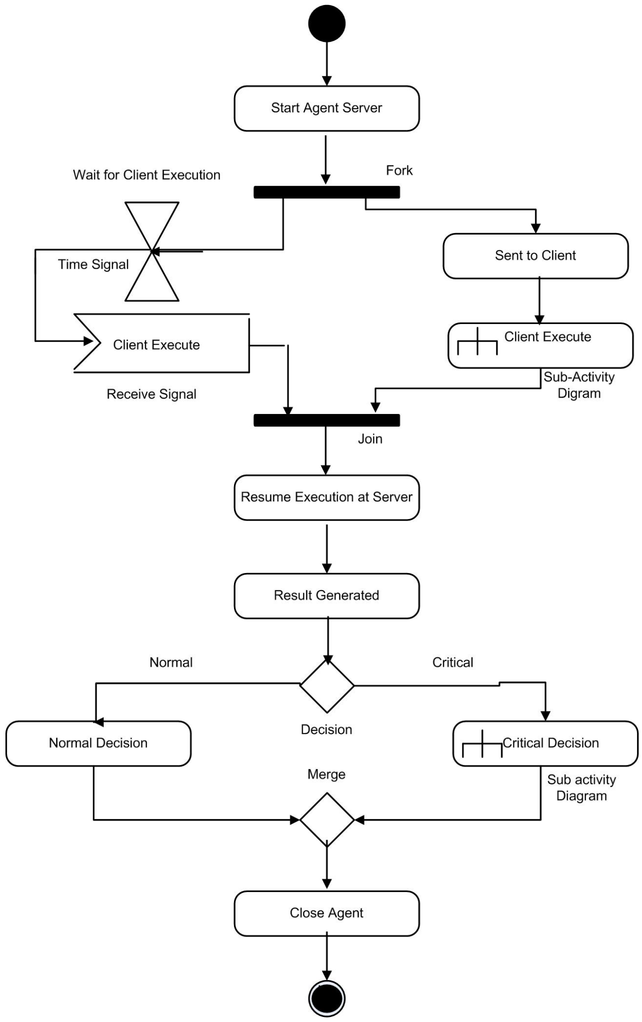

Fig. 3. Activity Diagram of Mobility

II. THE MODEL BASED ON ACTIVITY DIGRAM

Activity diagram made up of actions based on nodes. There is a start and stop symbol known as initial and final node of activity. Initial node is representing by a single filled circle while final by two concentric circles. Activity diagram has some specific symbols to represent the logic.

- Fork: A fork has single input flows and multiple output concurrent flows. It is represented by a heavy bar. Using fork concurrent threads can be created simultaneously. Each thread can be executed without interrupting to other.
- Join: A join is similar to fork symbol but opposite in behave. A join has multiple input flows and a single output. It is used to reduce the threads generated by fork. Multiple fork and join can be used, but there must be a corresponding join to a fork symbol. Multiple threads

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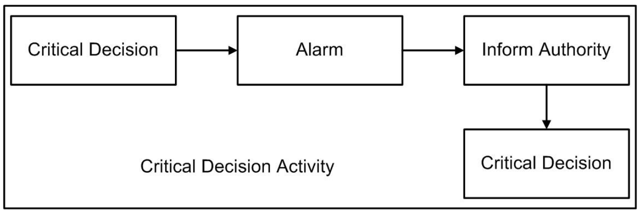

Fig. 4. Sub Activity Diagram of Server

created by fork execute independently and back to join for generating single output.

- Decision: A decision has a single input flow and several guarded [conditional] outbound flows. Every outbound flow has a guard: a Boolean condition. Whenever the decision executes, only one outbound flow will be selected, so showing guards are mutually exclusive.
- Merge: A merge has multiple incoming flows and results as a single output. A merge marks the end of conditional behavior started by a decision.
- Action Decomposition: Activities actions can be decomposed into sub-activities.
- Time Signal: It occurs because of the passage of time. Such signals might show some specific period (wait) for an external process.
- Accepting Signal: It is useful when to send a message and then wait for a reply before to continue.

In our model the mobile agents behave on different nodes concurrently. To represent this scenario, activity diagram is selected. The process of flood prediction commence by the creation of mobile agent at server node as shown in the Fig.3. At the point, mobile agent code is divided into two parts one for the server and another for client using the symbol fork. At the server, we use the time signal, shows the waiting of client code execution. At other end, client starts execution and generates a required result that is represented by a sub-activity diagram of client as shown in Fig.2. It is responsible for reading velocity and level of water. Further, it calculates the discharge of water by taking the current values of velocity and level of the water. Moreover, mobile agent executes at client to transform the required code to the server. As the mobile agent received to the server, it restarts its execution. This execution at server uses a symbol Join, shows two incoming flows, one from client and other from server. This compares result of clients with historical data of previous flood for prediction. Server uses decision symbol indicting normal or critical flow of water. Server is responsible for flood prediction and calculating inundation area, it uses alarm in critical situation for securing inhabitants of the particular area. This critical situation is represented by the Fig.4. Server categorized the flood in different phases based on discharge and risk. In normal flow, server takes no actions but in critical situation it calculates inundation area based on discharge value.

III. SPECIFICATION AND VERIFICATION OF THE SYSTEM

In the Fig.5 the mobile Petri net MPN is constructed which shows the process of communication of the server agent with the client agent based on mobile agent approach. In the MPN, the marked place and the transition represent the sequence of

TABLE I
DESCRIPTION OF PLACES AND TRANSITIONS

S#	Places/Transition	Description
1	p1	Server Agent
2	p2	Request to Client
3	p3	Client Execution at Server
4	p4	Flood Database
5	p5	Prediction of Flood
6	p6	Client Agent
7	p7	Read the Speed of flood
8	p8	Read the Level of flood
9	p9	Area of the Cross-section
10	p10	Discharge of flood
11	t1	Initiation of Server
12	t2	Prediction by Server
13	t3	Reading the Flood
14	t4	calculating the Area
15	t5	calculating the Discharge
16	t6	Reinitiation of the Server after the fixed interval

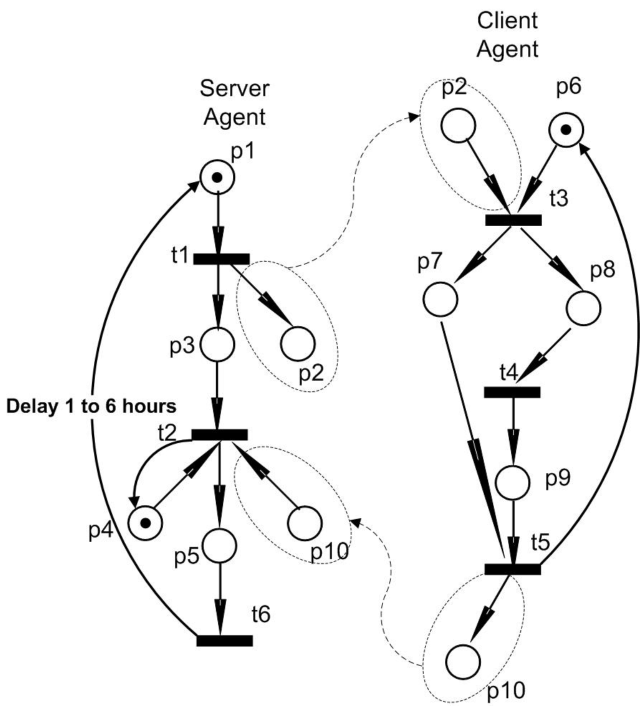

Fig. 5. Specification of the model

operations. The transitions denote starting or finishing of the operations while places represent the operations and resource types. The interpretation of places and transitions are given in Table 1. In the specification the server and the client shown in the Figure consists on two mobile petri nets:

$$MPN_{server} = \{P_s, T_s, I_s, O_s, M_{cs}, f_s, M_{os}\}$$
$$\text{and } MPN_{client} = \{P_c, T_c, I_c, O_c, M_{cc}, f_c, M_{oc}\}$$

where $P_s = \{p_1, p_2, p_3, p_4, p_5\}$ are the places and $T_s = \{t_1, t_2, t_3\}$ are the transitions. The set $M_{cs} = \{p_2\}$ represents the mobile agent of server used to communicate with the client agent. Since has only one token and $O(p_1) = \{t_1\}$ hence p_1 can enable t_1 it represents the transition of the server towards the set of places $\{p_1, p_2\}$. Where p_2 is the

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Mi	Marking	Description
M1	P1+p4+p6	Initiation of server
M2	P2+p3+p4+p6	Execution of client
M3	P3+p4+p7+p8	Calculating speed and level of flood
M4	P3+p4+p7+p9	Area of cross-section +speed of flood
M5	P3+p4+p10+p6	Discharge of flood
M6	P1+p4+p6	Prediction of disaster area
M7	P3+p4+p10+p6	Initiation of server after fixed interval

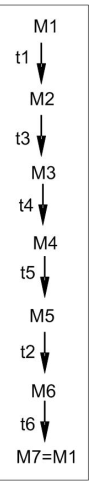

Fig. 6. Verification of the model

mobile agent uses to activate the mobile Petri net MPN_{client} of the client agent. The specification of client mobile Petri net containing $P_c = \{p_6, p_7, p_8, p_9, p_{10}\}$, $T_c = \{t_3, t_4, t_5\}$ and the set $M_{cc} = \{p_{10}\}$. When the server is required to check the status of the client, it dispatches the mobile agent $\{p_2\}$. This describes the request of the server to know the current status of the client. In the real sense the data of a flood is usually required with the interval of one to six hours, where one hour in the critical condition and six hours in the normal situation. The mobile agent $\{p_2\}$of the server enables the transition of the client agent. This further activates the activities denoted by $\{p_7\}$and $\{p_8\}$. The $\{p_7\}$ reads the flood speed and $\{p_8\}$ reads the flood levels. Moreover, the condition $\{p_8\}$ enables the transition t4 uses the level of a flood to calculate the cross-section area of the region denoted by $\{p_9\}$ through which the flood is passing. At the end of client execution the conditions $\{p_8\}$ and $\{p_9\}$ enables the transition t_5 which creates the mobile agent $\{p_{10}\}$ to the server contains the discharge of the flood. In server agent, the mobile agent $\{p_{10}\}$ combined with $\{p_3\}$ and $\{p_4\}$ enables the transition t_2. The activity $\{p_4\}$ represents the existing database of the flood and disaster caused. The transition t_2 activates $\{p_5\}$ provides the prediction of the inundation areas. Finally, $\{p_5\}$ enables the transition t_6 which reinitiate the server after the fixed interval varying from 1 to 6 hours, depends on the situation of a flood. This is designed by the special arc with delay option.

A. Verification of the System

To check whether there exist one-to-one functional correspondence between the Petri net model and the original requirements specification. For this we use the reachability tree which is extremely useful for the analysis of PNs. This method involves the enumeration of all reachable markings or their coverable markings. The Fig.6 shows the reachability tree of the model and each marking in the tree lists the places holding a token. The reachability tree represents the reachable states of a PN from initial marking $\{p_1+p_4+p_6\}$.

In the tree every node represent markings generated and edge from one marking to another represents the transition fired. Moreover, from the Figure it is depicted that each new marking enables single transition and leads to single new marking. It is clear from the tree that the final marking is reachable from their respective initial marking which represents the passing message from the server to the client and then it ends at the prediction of inundation areas. Every marking includes the set of places holding a token showing that the modeled system is safe and the system is under control. The final marking represents the successful operation of the server and client which predicts at server. Moreover, every marking enables a transition showing the absence of deadlock in the system.

IV. Conclusion

Flood is always a permanent threat for human lives. Efficient prediction techniques can help in securing people of inundation area. Existing techniques are not taking the benefits of advancement of technology developed in recent era. We proposed a model based mobile agent concepts for flood prediction. The specification of the model is presented by the UML-activity diagram. It described the activities and actions which supported concurrent mobility of mobile agents in the system. Further, the whole system is specified by mobile Petri net and then verified by the reachibility graph. This shows that the system has no deadlock and under control.

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