In this chapter, we design a River Flow Management System (RIFMAS) using SAP. In this system we are mainly using MAs, WSN and intelligent systems (SAP) to manage the water flow of a river by continuously monitoring the precipitation and correspondingly changing the position of the diversion head regulators (HRs) of a barrage.

Rest of the chapter is organized as follows. Section 8.1 highlights on issues and System Model is given in Section 8.2. Section 8.3 presents System Architecture and Implementation of the System is given in Section 8.4. Section 8.5 gives simulation of RIFMAS. Future model of RIFMAS, i.e., GRIFMAS and its implementation is discussed in Section 8.6 & 8.7 respectively. Limitation of RIFMAS is given in Section 8.8 and finally the chapter is summarized in Section 8.9.

8.1 Issues
The growing need of automation and the application of the sensors in the real world have provided dynamicity to both the physical and the virtual world. Small mobile sensing agents (MSAs) in a network have made it possible to collect and estimate the data of the physical phenomenon with precision and accuracy which was however impossible or difficult to calibrate. MSAs are the most powerful means of observing the variety of variations in the variety of events over a large period of time. In the network a large number of MSAs communicate over short-range wireless interfaces to deliver observations and stimuli to BS. This data is then acted upon by an intelligent system and can be worked upon accordingly. MSAs facilitate the human life by providing ubiquitous sensing, computing and communication capability which help in observing and interacting with the environment. Floods have always been a major cause of destruction from the past itself. In the manual river flow control system there is always a situation of the increasing or decreasing of the discharge available depending on the precipitation
of the catchment region. Thus, we need a system for monitoring the critical situation of rivers and action upon barrages of the rivers accordingly.

8.2 System Model

In the trivial river flow control systems we firstly measure the total precipitation at the various rain gauge centers. Secondly, based on these readings the discharge that flows out of the catchment is calculated. Thirdly, the time taken by the discharge to reach the HR of the barrage is calculated which is generally constant for a particular barrage setup and its catchment. Fourthly, as soon as the estimated discharge and the time are estimated this data is fed to the barrage section. Fifthly, as the data arrives the barrage is set in accordance to the provided values (manually). The following is challengeable- detecting the precipitation, monitoring, collection and calibration of the data, assessing and evaluation of discharge information, formulating meaningful user displays, and decision making with emergency and alarm functionalities and form the mainstay for sensing as well as for the first stages of the processing hierarchy. This application of wireless sensor networks is expected to be a precursor of the modern day river monitoring and Flow control systems.

8.3 System Architecture

A River Flow Management System (RIFMAS) which is intended to make the flood management system automated adaptive and autonomous to support advanced management services of rainfall data and information mining in order to avoid floods. RIFMAS deploys the MSAs to make this process self-operational in nature so that the system in itself controls the movement of the HR depending on the estimated discharge. The information needed by the system is provided by SSA. The System Architecture of RIFMAS shown in Figure 8.1 comprises the following.

(a) Sensing Agent (NODE 1 to N): These are the MICA2 MOTE sensors by crossbow which are being deployed to measure the precipitation in the catchment region. These sensors are integrated with MAs. These MAs are used to measure the precipitation level in inches. MA carries these sensed data to the Data Collector (DC).
(b) DATA COLLECTOR (DC): collects and assemble data and provides this data to the Data Processing and Management Unit (DPMU) using MAs. (DC could also be used as a server for maintaining the database of the rainfall data by the metrological department). DC actually acts as a mediator between the DPMU and the Gate Manager (GM). DC works like sink.

(c) Data Processing & Management Unit (DPMU): collects the data from the DC and calibrate it to Q_DISCHARGE and EST_TIME. The DPMU executes MAs for calibration charts to estimate Q_DISCHARGE. The EST_TIME is generally constant for a particular catchment. The DPMU forwards a MA with estimated data back to the DC.

(d) GATE MANAGER (GM): The DC sends the calibrated Q_DISCHARGE and EST_TIME to the GM. The GM takes Q_DISCHARGE as input and performs the following operation over it. Divide the Q_DISCHARGE into Q1_DISCHARGE, Q2_DISCHARGE, and QM_DISCHARGE in a predefined ratio. Calculate the Gate Openings for the divided data, i.e., Q1_HOPENING, Q2_HOPENING, and QM_HOPENING.

*Figure 8.1: System Architecture of RIFMAS*
Set the gates to these values so as the discharge reaches the gates and the gates should be set to receive that amount of discharge.

### 8.4 Implementation of RIFMAS

Figure 8.2 shows the implementation model of the RIFMAS. The data read from the sensing agent (SSA) is acted upon by the system and computes the relevant discharge, and using MA the data is transferred to the Barrage section, which operates accordingly. A brief discussion is as follows.

![Implementation Model of RIFMAS](image)

**Figure 8.2:** Implementation Model of RIFMAS

The sensing agents (node 1, node 2 . . . node N) correspond to the motes deployed for the sensing purposes. These agents are sensing the precipitations (PPtn1, PPtn2… PPtnN) corresponding to each node. In the trivial system these are the rainfall gauging stations under the supervision of the Metrological Department which continuously monitor the rainfall and are fixed for a particular catchment as shown in Figure 8.3.
The data collected from the various gauging stations is reported to a main data station (data collector). This station estimates the \( Q_{\text{DISCHARGE}} \) and secondly \( \text{EST\_TIME} \) for the discharge, i.e., the time to reach the HR which is generally constant for a particular barrage and a main data station. The estimated \( Q_{\text{DISCHARGE}} \) and \( \text{EST\_TIME} \) are then reported to main data centre to the Barrage section using a MA.

The data received is now acted upon by an intelligent calibrating agent (ICA) which decides \( Q_{\text{1\_DISCHARGE}} \), \( Q_{\text{2\_DISCHARGE}} \) and \( Q_{\text{M\_DISCHARGE}} \) depending upon the total capacities of the canals or in the same ratio. ICA also divides the received data as per the need of the application. Depending on the respective discharges \( Q_{\text{1\_DISCHARGE}} \), \( Q_{\text{2\_DISCHARGE}} \), and \( Q_{\text{M\_DISCHARGE}} \), ICA computes the respective head movements, i.e., \( Q_{\text{1\_Hopening}} \), \( Q_{\text{2\_Hopening}} \), \( Q_{\text{M\_HOPENING}} \), respectively. Now when the discharges and the corresponding gate openings are calculated for the respective canals, the gates of the HR are set on the values decided earlier, i.e., \( Q_{\text{1\_Hopening}} \), \( Q_{\text{2\_Hopening}} \) and \( Q_{\text{M\_HOPENING}} \).

The data is collected at a clock of 15 minutes and depending on the pond level, Highest Flood Level and the Crest Level will adjust the Head Opening. The inputs are queued in a system queue and the Head regulator takes input from that queue. If the central data station senses \( Q_{\text{DISCHARGE}} \) above the maximum limit of the canals and the main stream this sends an emergency flag signal to the Barrage so
as the gates are immediately set to the maximum value in order to allow a maximum room for incoming excess flow. Operation cycle is shown in Figure 8.4.

![Figure 8.4: Operation cycle of the RIFMAS](image)

The RIFMAS provides us with the following functionalities:

- The precipitation of the catchment is measured.
- This precipitation is successfully calibrated into the discharge of the catchment.
- This discharge is successfully divided into the sections in the desired ratios.
- HR is moved in accordance with the estimated discharges.
- The system sets the gates value to the maximum if it receives a flagged message from the upstream data station.

### 8.5 Simulation

A calibration simulator which takes PPt^1, PPt^2, ..., PPt^N as observed precipitation and returns Q1_DISCHARGE, Q2_DISCHARGE, QM_DISCHARGE and Q1_Hopening, Q2_Hopening, QM_Hopening has been produced and is efficiently working for the desired or random discharge inputs to the system. For simulating the RIFMAS we have used the water distribution strategy at barrage as shown in Figure 5. Here incoming Q_DISCHARGE is divided into Q1_DISCHARGE, Q2_DISCHARGE, and QM_DISCHARGE.
Figure 8.5: Distribution strategy at Barrage

Figure 6 highlights the variation of the total discharge of the catchment (Q_DISCHARGE) in cusecs with the precipitation (PPr“N). With the help of this chart we could estimate the total discharge from the catchment area depending upon the precipitation level. There may be a variation of 10%-20% in the above values depending upon the precipitation.

Figure 7 shows the amount of discharge flowing through the canals, i.e., Q1_DISCHARGE, Q2_DISCHARGE and QM_DISCHARGE on Q1_HOPENING, Q2_HOPENING and Q3_HOPENING respectively.

Figure 8 presents the distribution of Q_DISCHARGE into Q1_DISCHARGE, Q2_DISCHARGE, QM_DISCHARGE depending on the ratios of the maximum carrying capacities. This can also be modified as per the needs of the situation.

Figure 8.6: Variation of Discharge with precipitation
Figure 8.7: Discharge vs. Head Movement

Figure 8.8: Discharge Distribution

Figure 9 shows the value for EST_TIME (constant) for catchment area. It is 67 minutes for the catchment under study.

Figure 8.9: EST_TIME
8.6 Global RIFMAS: GRIFMAS

In Figure 8.5, there is no escape if $Q_{\text{DISCHARGE}}$ exceeds the maximum value, i.e., $Q1_{\text{DISCHARGE}}+Q2_{\text{DISCHARGE}}+QM_{\text{DISCHARGE}}$. In this situation flood cannot be stopped. This is the motivation factor for GRIFMAS which is a futuristic implementation model of the proposed scheme. The implementation model of GRIFMAS is shown in Figure 8.10(a). The implementation model of GRIFMAS includes the following parts. **River Control Station (RCS A-N):** This is the central control for a particular which controls all the RIFMAS stations and houses the current data of water flowing through various catchments into the river flow. Data from each of the RIFMAS stations is collected using MA $\mathcal{A}$ as shown in Figure 8.10(b). **Global Monitoring Station (GMS):** All the RCS stations are centrally controlled by this unit. GMS also receives any alarming signals from the RCS stations and in acknowledgement broadcasts an alarming signal to all the RCS sections. It also computes the best and the shortest path for the overflowing discharge. This information is again broadcasted to the respective RCS stations.

8.7 Implementation of GRIFMAS

All the RIFMAS stations are deployed at the various catchment regions. These RIFMAS stations are then in turn connected to the RCS stations which are actually deployed for each of the river. The RCS stations are updated through the information regularly about proper functioning of each RIFMAS station. As soon as any alarming value of discharge is estimated by any of the RIFMAS stations it reports this to its respective RCS center. On arrival of alarm RCS sends an emergency signal to the GMS. The GMS then broadcasts a packet to all RCS centers demanding the current status of each of the RCS centers and the RCS centers acknowledge this signal. With this collected data the GMS computes shortest path through all the catchment in the downstream to the catchment which issued alarming signal. This shortest path has the following features.

(a) It includes the canals and streams which are in downstream only.
(b) The path may include even those canals which are running to maximum capacity, i.e., we keep the amount of water added and taken out to be equal.
(c) The path is found using a weighted graph so the cost factor is considered beforehand only. As soon as the graph is computed the emergency gates at each of the RIFMAS stations are set open.

The system operates till stable values of precipitation are sensed by sensors at the RIFMAS stations.

![Diagram of GRIFMAS system](image)

**Figure 8.10:** Data Gathering in GRIFMAS Using MAs

### 8.8 Limitation of RIFMAS

The safety and proper functioning of the SN in moist conditions are a primary cause of concern for the proper functioning of the RIFMAS. Battery backup of the
sensing agent is another issue of concern. It is required to replace the sensors/battery at regular intervals of time.

8.9 Summary
In this chapter we have presented a MSAs based RIFMAS to manage and control the flow of a river stream. It can also be deployed for the water distribution purposes. Extended model of RIFMAS is GRIFMAS is also presented. Next chapter will conclude the work presented in this dissertation.