

Student-Paper
on
”Collecting Seismic Data
Over Packet Radio”

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1 Introduction

1.1 The Problem

Indonesia has about 120 volcanos. The volcano experts found out that each of this volcanos has a characteristic 'tounge' which tells what will happen (e.g. eruptions or an outbreak). It would be interesting to get all the data into a central office to fit the following goals:

- learning more about the volcanos for research
- getting continual information of any seismic activity
- civil protection

The difficulty is the lack of infrastructure on the one hand, because it is not easily possible to interconnect so many stations with public networks. On the other hand such a solution would be very expensive, because phone cost depend on distance and Indonesia is a big country.

1.2 The Group

There are several roles in this project:

Customer The University of Indonesia, Dr. Kirbani

Project Leader in Salzburg Prof. Dr. G. Mayer

Project Members Eight students are working in the group of Prof. Mayer. There are several subgroups (Central Station, Packet Radio, Data Acquisition), each will solve a marked out field.

2 System Design

2.1 Prerequisites

There are several prerequisites we know from Dr. Kirbani and Dr. Mayer, which should be taken in consideration.

- No infrastructure can be expected. The outdoor station should run autonomously.
- To transmit the data to the center an existing packet radio network can be used. This system is called 'Jasipakta' and is maintained by LAPAN, the Indonesian National Aerospace Agency. It provides an uplink bandwidth of 9600 bps and a backbone bandwidth of 56000 bps.
- The seismic activities should be measured by a geophone. The used model can recognize frequencies from 0.005 to 40 Hz and slopes of 1000 V/ms.

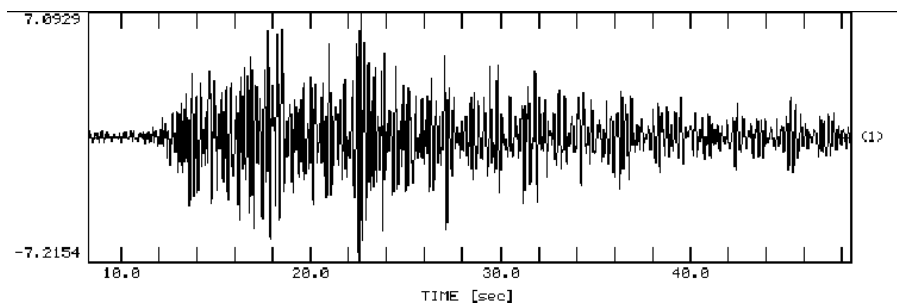


Figure 1: Example of a recorded eruption

2.2 Principle Design

The whole system consists of six main parts.

- Data Acquisition (DAQ)
- Data Processing and Control (DPC)
- Time System (TSY)
- Data Transmission (DTR)
- Power Supply Unit (PSU)
- Data Evaluation and Display (DED)

Additional Equipment could be integrated, e.g. a weatherstation.

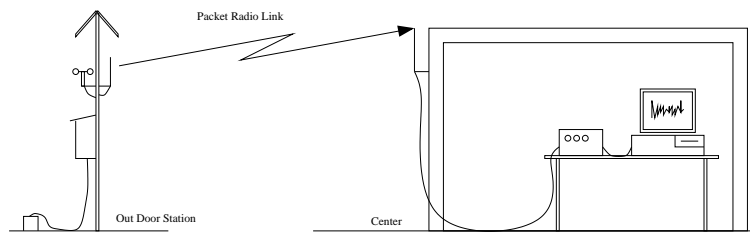


Figure 2: Principle design of the whole system

2.2.1 Data Acquisition (DAQ)

This part consists of all hard- and software which handles with the collection of data.

The seismic data will be gathered by a geophone. This device has three output values, x-, y- and z-oriented measured forces.

2.2.2 Data Processing and Control (DPC)

The Data Processing and Control Unit timestamps and stores the recorded data till they are successfully sent to the center. The DPC unit also controls the station as itself. This means house keeping (alarm functions for errors and break in, energy management, maintenance functions).

2.2.3 Time System (TSY)

To fix the exact time of each event the same time is needed on all stations. One System that can provide this worldwide is the General Positioning System (GPS). GPS data should be used as reference for the system time at the data processing system.

2.2.4 Data Transmission (DTR)

Data should be transmitted wireless because of the lack of infrastructure. One cheap possible way is the use of packet radio. In Indonesia there is already an existing packet radio network called "Jasipakta", which is maintained by LAPAN, the Indonesian National Aerospace Agency. This network is also connected to the Internet.

2.2.5 Power Supply Unit (PSU)

The outdoor station needs an autonomous power supply because of the lack of infrastructure. A possible way is to use solar power to provide the devices with enough energy.

2.2.6 Data Evaluation and Display (DED)

From each station the data should be collected in a center, which archives, evaluates and displays the data.

3 The Outdoor Station

3.1 General

The outdoor station consists of the parts DAQ, TSY, DPC, DTR and PSU. The following parts will be used:

- DPC consists of a small Personal Computer system PC/104. This PC will be supplied by a 12 VDC-System. This System also holds an analog digital converter (ADC) with more than 8 ports and several digital IOs. The operating system and the application should be stored on a flash RAM. No conventional hard disk system will be used, because of reliability and power consumption.
- The system time of the DPC will be set by a GPS clock. DPC and TSY are connected via a serial V.24 cable. The operating system should understand the protocol standard of the GPS clock.
- The seismic data will be provided by a geophone. Three analog outputs are available for x- y- and z-direction forces. Because of the given frequencies, the sample rate of the DAQ should be greater than 80 Hz.
- The data transmission unit consists of a Terminal Node Controller (TNC) which is connected via a serial V.24 cable with the DPC. The TNC converts the digital data in analog data and does several protocol work. This analog signal will be transmitted/received by a amateur radio station. Since packet radio is used several digipeater can be put between the outdoor and center station.
- The power supply unit consists of a fotovoltaic panel, a rechargeable battery and the charging electronic. The supply voltage is 12 VDC.

3.2 General Requirements

- Geophone: The seismometer will be a Lennartz LE-3D/20s as Dr. Kirbani claimed.
 - Frequency: 3x 40Hz
 - Minimum Sampling Range: > 80 samples/second
 - Used Sampling Rate: 1000 samples/second (for software filters)
 - ADC-Resolution: 8..12 Bit
- Time-System:
 - precision: $\pm 10ms$

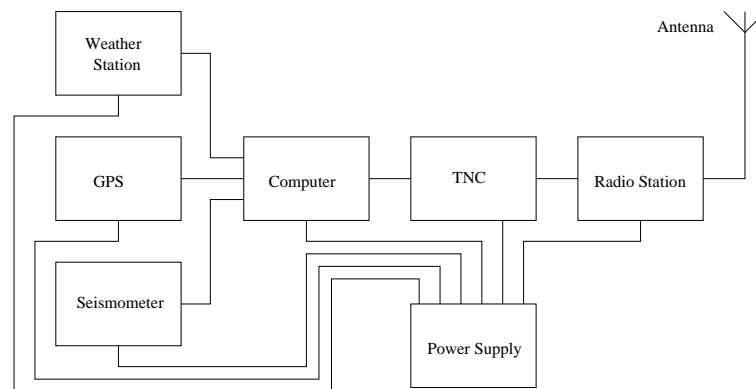


Figure 3: Principle design of the outdoor station

3.3 Maintenance

The field stations are located around the volcano, therefore they might be difficult to reach, especially for maintenance reason. To provide a way to remotely maintain the field stations will be not only convenient but also mandatory. We have to differentiate two forms of maintenance:

- the maintenance and tuning of the running programs to analyze and transmit the data, ... This is done mainly during the field tests by an experienced technician.
- the maintenance of the station e.g. charging state of the battery, running tests of the system, ... These are periodic tests which should be performed even by a less experienced "normal" user.

The stations are connected over a AX.25 network to the central station. As it is possible to run TCP/IP over AX.25 the best way to provide access for the experienced technician is through ssh. For the periodic access performed by the "normal" user there must be a client/server structure with an User Interface.

4 Data Processing and Control (DPC)

The goal is to not to transfer all data coming from the seismometer but only the interesting one. This is a mandatory prerequisite because of the limited bandwidth of the used packet radio backbone.

4.1 Concept

The idea is to record the data coming from the seismometer and split them up in segments with a length of e.g. 1 minute duration (The optimal length will be determined during the field tests). The segments will be analyzed and if an seismic activity is ascertained, this segment will be transmitted to the central station. Segments with no activity will be discarded.

There are two critical parts in this concepts:

- First of all the process of analyzing the data and determining the segments with activity has to be faster than new data arrives. This might be clear, but it has to be mentioned that on the same systems also other processes may be running e.g. the process responsible for data transmission (packet radio), maintenance processes, ...
- The way of determine an activity in a segment is decisive for the quality of the whole system. Only the user (scientists) can give an answer to the question how to recognize activity. The first suggestion is to use a threshold, but this may change during the field tests. It would be best to provide a way to change the activity determent function remotely from the central station.

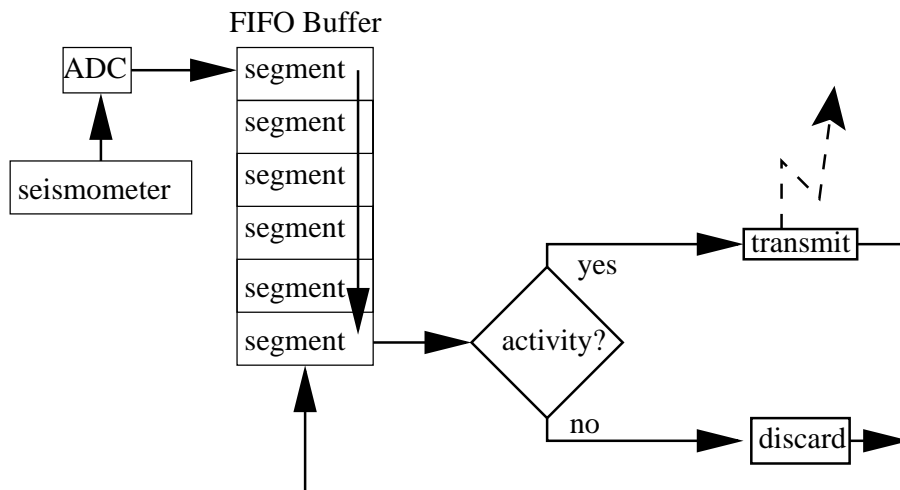


Figure 4: schematic concept of data acquisition

5 Data Transmission (DTR)

5.1 Introduction

Radio amateurs have developed packet radio for more than 20 years now and have constituted a worldwide network supported by a constellation of satellites. The choice of amateur radio hardware and software was motivated by its low price, proven reliability and large choice.

The basic equipment to access or create a network is a radio, a TNC (Terminal Node Controller) and a computer or terminal. The TNC chosen has a 9600 bit/s raw bit rate on his radio port and the radio is a 2 W UHF transceiver.

As suggested by its name the TNC can act as a node and as a terminal simultaneously. The TNC alone acts as a repeater ("digipeater" in amateur radio terms). With a computer connected to its serial port, more sophisticated routing functions can be added. Softwares exist to replace the original repeater function by higher level routing functions but most of the time the terminal function of the TNC is then lost. The digipeating scheme is not efficient in noisy environments if the number of hop between the source and the destination is greater than 1. A packet lost on any segment of the link will be retransmitted starting from the source even if it successfully crossed the first segments. Delays and low throughput appear on a digipeater based network.

Most instruments cannot be connected directly to the serial port of the TNC. For volcano monitoring application, it is costly and not practical to install a computer to every node of the network. So another kind of interface is needed.

That is why we decided to use a micro controller instead of a computer.

5.2 Packet Radio

5.2.1 The Protocol - AX.25

AX.25 is the link access protocol for amateur packet radio.

The amateur radio community has expressed the need and desire to define a protocol that can accept and reliably deliver data over a variety of communications links between two signaling terminals. The AX.25 version 2.2 Link-Layer Protocol provides this service, independent of the existence of any upper layer.

As defined, this protocol works equally well in either half- or full-duplex amateur radio environments, and has been improved for operation over partially impaired HF circuits.

Basic Concepts ISO has developed a reference model for Open Systems Interconnection (OSI) to better facilitate the interconnection of different types of computing systems. The basic structuring technique in this reference model is known as layering. According to this technique, communication among application processes is viewed as being logically partitioned into an ordered set of layers represented in a vertical sequence as shown in Figure 5

Each layer provides a Service Access Point (SAP) for interface to the next higher layer. Note that any layer may be a null, where no function or code is provided. Such is the case with the current TAPR TNC-2 equipment, where only Layers 1, 2 and 7 are provided; these comprise the minimum configuration for reliable communications.

Layer	Function
7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data Link
1	Physical

Figure 5: OSI-Model

AX.25 Model The two lower layers, data link and physical, can be further subdivided into several distinct finite state machines as shown in Figure 6. This example shows a single link to the radio port.

Frame Structure Link layer packet radio transmissions are sent in small blocks of data, called frames. There are three general types of AX.25 frames:

- Information frame (I frame);
- Supervisory frame (S frame); and
- Unnumbered frame (U frame).

Layer	Function(s)	
Data Link (2)	Segmenter	Management Data Link
	Data Link	
	Link Multiplexer	
Physical (1)	Physical	
	Silicon/Radio	

Figure 6: AX.25-Model

Each frame is made up of several smaller groups, called fields. Figure 7 and Figure 8 illustrate the three basic types of frames. Note that the first bit to be transmitted is on the left side.

Flag	Address	Control	Info	FCS	Flag
01111110	112/224 Bits	8/16 Bits	N*8 Bits	16 Bits	01111110

Figure 7: U and S frame construction

Flag	Address	Control	PID	Info	FCS	Flag
01111110	112/224 Bits	8/16 Bits	8 Bits	N*8 Bits	16 Bits	01111110

Figure 8: Information Frame construction

5.3 Operating System

We have chosen to use a small version of the Linux operating system called LoopHam. The system can be installed on and run from any DOS system (MS-DOS (etc) and win95/98 in dos mode). It is hacked from LoopLinux Version 22. The distribution contains all AX.25 ham needed packages. The System needs at least 8MB of RAM and X368 Processor, or higher. The following Hardware is supported by the System:

- ISA, EISA, PCI, motherboards...
- IDE hard drives and IDE/ATAPI cdrom drives...

- SCSI hard drives and cdrom drives...
- MCA (M)icro (C)hannel Bus Support...
- PS/2 ESDI hard drives...
- Non Atapi/Scsi cdrom drives...
- Standard + LS-120 floppy drives...
- Parallel port printers...
- Serial and PS/2 mice...
- PNP support...
- Non serial mice...
- PCMCIA support...
- ETHERNET cards...
- AX25 hardware

5.3.1 Included Libraries

The following Software is included in the LoopHam System:

- bash (Shell...v2.04)
- fetchmail (Pop2, Pop3, APOP, IMAP, RPOP, ETRN, mail client...v5.4.3)
- lynx (Lynx WWW Browser with slang color...v2.8.4dev.3)
- mc (Midnight Commander file manager, also does excellent ftp...v4.5.51)
- metamail (Mail filter...v2.7)
- minicom (Modem terminal program, with X, Y, Zmodem...v1.83.1beta)
- mutt (Mail client-reader...v1.2.4 with 'POP3' and 'IMAP')
- ncftp (Ftp client...v3.0.1)
- procmail (Mail processing program...v3.15)
- sendmail (Mail delivery program...v8.11.0.beta3)
- telnet rlogin finger nslookup ping host vrfy whois
- tin (Newsreader with color support...v1.4.4)

- rtin (Remote tin = tin -radnq)
- wget (WWW URL and FTP retrieval program...v1.5.3)
- Modutils "v2.3.11"
- patch "v2.5.4"
- diffutils "v2.7.2"
- sysvinit "v2.78"
- procps "v2.0.6"
- gawk "v3.0.4"
- sed "v3.0.2"
- ppp "v2.4.0b2"
- arachne "v1.66b" Graphic web browser svgalib
- Boa web server "V0.92"
- Bind (name server) "V8.2"
- Jnos 1.11E "compiled by f5nlg"
- Dxnet from F5MZN "V3.4"
- Colrconv "V0.99.2.4"
- Htppu URO "V1.3"
- Awznode "V0.4C" (flexnet node compatible)
- LinPac "V0.13"
- Ax25-apps "V0.0.4"
- Ax25-tools "V0.0.6"
- libax25 "V0.0.7"
- Z8530drv-utils "V3.0"
- Hamconf configuration script "V1.1" (F5NLG)
- Somme modules for ppp,slip, Ax25, ethernet see it in /lib/modules/2.2.16/

5.3.2 Configuration

5.4 Interface to Data Processing and Control

The Communication between the DPC (Data Processing and Control) process and the DTR (Data Transmission) process will use AF_UNIX-Domain Sockets. Whenever DPC finds some relevant data to transmit it sends it plain through the socket. The DTR process is then responsible for buffering the data, appending protocol header information and transmitting it via packet radio to the central station.

5.5 Packet Radio Controller RPC-433 from Radiometrix

Also see <http://www.radiometrix.co.uk/products/product1.htm>

The consideration was to use cheap system consisting out of a industrial computer and a cheap transceiving packet radio unit. There was an offer from Radiometrix that seam to comply with the requirements of the project.

5.5.1 Description

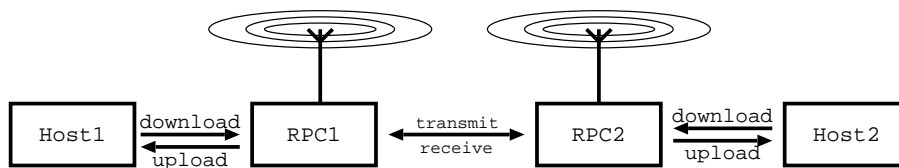


Figure 9: Datatransport between 2 Hosts

The RPC can send packets from 1 up to 27 byte with a sync-byte at the head of the packet and a control byte for transfer information between the Host and the RPC. The Rest of the packet is for data, routing-information and other protocol specific implementation. The baudrate is 1200Hz. The RPC provides collision avoidance (listen before transmit) and error detection. One byte will be extended to a 12 bit code word. First there is a 20KHz preamble with a duration between 3ms and 5ms, which indicates the transfer of a packet. Afterwards follows the sync-byte. The RPC appends an 8 Bit checksum after the 27 byte Packet. All this will be extended by the error detection code to 43 byte. The packets are sent with a rate of 40Kbits/sec.

preamble	sync	controlbyte	data	checksum
3 - 5ms	01111110	12 bit	40.5 bit	12 bit

Figure 10: The packet for transmission

To get the net bit rate in Kbps we calculate the time, a packet with the maximum of size will be send. If we choose a lower size the overhead increase. This is not considered for this purpose. The maximum of net data per frame is 26 Byte. With a frame of 43 byte size and a transmission rate of 40 Kbps we get:

$$\frac{43 * 8bits}{40Kbps} = 8,6ms \quad \text{for transmissiontime}$$

We suggest the worst case for preamble with 5ms, that we add to the transmissiontime of the sent frame:

$$\text{Total time to send: } 8,6 + 5,0 = 13,6ms$$

$$\Rightarrow \text{net data rate: } \frac{26}{13,6} \approx 1912Bps$$

5.5.2 Advantages

One of the advantages are the savings in power because of this RPCs characteristic. Radiometrix specify a requirement of 5V in transfer mode and a supply of less then 20mA in sleep mode. The RPC will be waked up by it self when a preamble of a packet is detected. This will be accomplished in following way:

If the power saving modes have been enabled the RPC will pulse the receiver on, check for preamble and go back to SLEEP if nothing is found. The 'ON' time is 5ms, OFF time is programmable in the RPC s EEPROM and can vary between 22ms and 2.9s.

A second advantage is, that the RPC from Radiometrix is a relative cheap solution for transferring Data from A to B with Packet Radio.

The net data rate is an advantage for solutions not depending on other protocols.

5.5.3 Disadvantages

The protocol of the RPC is based on the AX.25 but with aggravating exceptions which enable the transfer from Data from this RPC to a Digipeater or a Host working with the standard of Packet Radio. This is a consequence of the incompatibility of these two protocols of AX.25 (digipeater,..) and that of the RPC.

6 Central Station

6.1 General

The Central Station is basically a normal Personal Computer in an office environment that receives data from the outdoor stations and stores it for further analysis. The requirements for the Central Station are explained in more detail in the next section.

6.2 Requirements

6.2.1 Receiving Data

The main task of the central station is to receive the data sent from the outdoor stations. The stations will transmit data at a rate of 9600 Baud. Therefore the central station must be able to handle approximately 1 Kbits/sec.

6.2.2 Storing Data

Once data is received, it must be stored for further analysis. It is the central stations responsibility to differentiate tectonic earthquake signals from noise (e.g. man made noise, and sea microseismas, as well as volcanic earthquakes) and to store only valid data. If all stations around the volcano simultaneously detect activity, it will be most probably that it comes from tectonic activities. Only these records should be stored.

In general there will be short-term events (20 min. per day) and long-term events (60 min. per month). To record them the total recording time per month can be calculated as follows:

$$Time = 60 \frac{min}{month} + 30days * 20 \frac{min}{day} = 660 \frac{min}{month}$$

In case of an event a field station will send approximately 240 Byte/min. So the disk space required for one station is:

$$DiskSpace = 60 \frac{min}{month} \text{ with } 240 \frac{Byte}{min} \approx 155 \frac{kByte}{month}$$

The network should start with 4 field stations. Therefore the central stations needs to store at least 620 Kbytes per month.

6.2.3 Make Data Available to Public

Once the data is stored, scientist and even the public (the recorded data is public domain) should be able to access it.

6.2.4 Viewing the Data

There should be a viewer application available that makes it possible to view the recorded data in a comfortable way. The viewer may not be a full-blown software for analysing tectonic earthquake signals but it should provide some basic calculations. For further analysis, it should be possible to export the data to other file formats.

6.3 Architecture

6.3.1 General

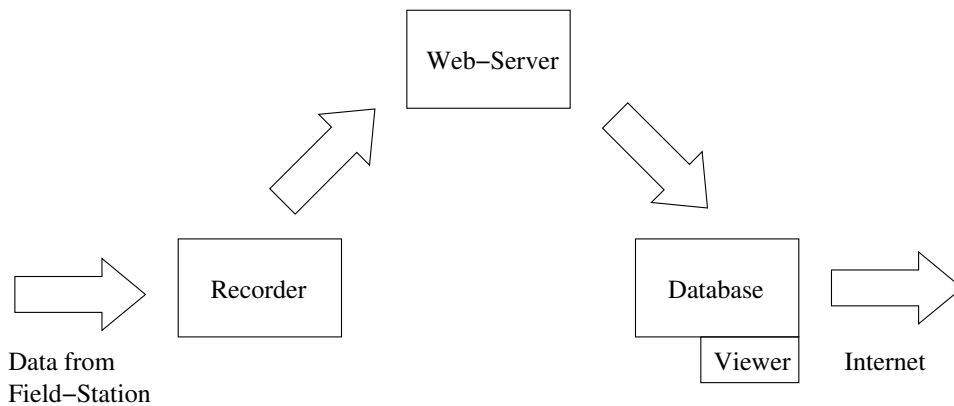


Figure 11: Overview of the central station

Figure 11 shows the architecture of the central station. Each rectangle represents a complete application that runs in its own memory. The applications can run on a single computer or they can be distributed on two or more machines.

6.3.2 Database

A database is used to store the records received from the field stations. There are advantages in using a database management system (DBMS) instead of the file system provided by the operating system:

Reliability: A DBMS automatically ensures the integrity of its content. So the recorder application does not have to care about it.

Easy Access: The selection of data (e.g. by event or by station) can be achieved more easily and effectively than using the file system.

Scalability: If required, the database, web server and recorder can be located on different machines. Database drivers will ensure the comfortable access to databases over the LAN.

6.3.3 Recorder

The recorder application will receive data from the field stations over packet radio. It will be stored in a database.

The advantage of the suggested architecture is that if there were problems with the DBMS, the recorder could buffer the data (e.g. in a file) until the DBMS is up again.

6.3.4 Web Server

Since the Internet is widely used, it is logical to use a web server to make the data in the database public.

6.3.5 Viewer

The Viewer is part of the web server. It should be a combination of HTML/JavaScript programs and Java applets that can be downloaded from the web server. This avoids a complicated distribution and installation of a viewer application.

6.4 Hardware Configuration

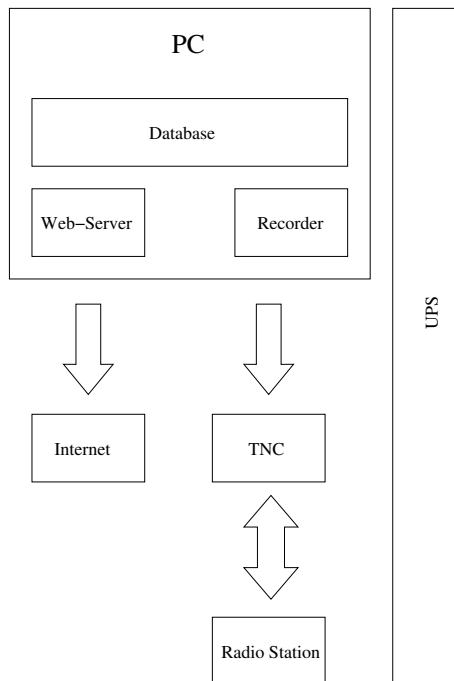


Figure 12: Hardware configuration with one personal computer

Figure 12 shows a hardware configuration where one computer runs all the required applications. It would be best to start with this configuration because it is the cheapest and easiest one. The first field tests will show whether it is sufficient or additional machines are required.

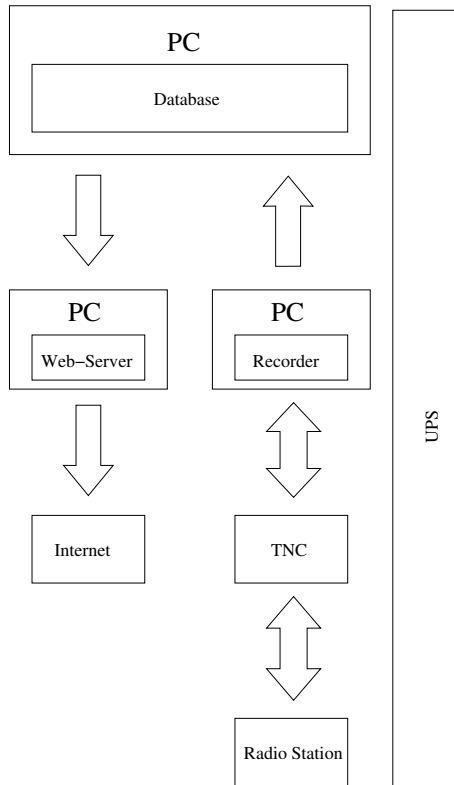


Figure 13: Extended hardware configuration

Figure 13 shows an extended hardware configuration where a computer runs only one application of the system.

The following components can be identified:

Computers: The computers can be “off-the-shelf” PC’s that can be purchased in normal shops. If one computer should run all the applications a memory upgrade to 1 GB is recommend.

Terminal Node Control (TNC): The TNC is used to access the packet radio network. It should at least support data rates of 9600 Baud.

Radio Station: It will bring the central station on air.

Uninterrupted power supply (UPS): The computers and the other equipment should be protected by means of UPS, because up to now the power line is not reliable, some times down and unstable.