Proceedings

Second International
Mobile Computing Conference

第 二 屆 國 際 行 動 計 算 會 議

National Chiao Tung University, ROC
March 25-27, 1996

Sponsored by the Ministry of Education, ROC
Sponsored by Computer Systems Research Center
in cooperation with the National Science Council

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Implementation Experience of a Mobile Workstation

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Abstract - This paper describes a practical experiment on building a radio mobile workstation in Taiwan. The mobile workstation consists of a mobile radio telephone, a portable computer, and some connected interfaces. Because of the noise interference, the coding scheme used in this project provides error-detection, error-correction, and data secrecy. The remote file server can communicate with the mobile workstation wherever it is, and gives immediate response.

I. Introduction.

In 1989 the **Taiwan Telephone and Telegraph Office** established the business in the **Mobile Radio Telephone (MRT)**. Only 2 types of MRT were permitted at that time: they are the 4W MRT for automobile and the 1.6W for portable. This business not only opens up its service scope but also provides unlimited application of the computer radio communication. This permits a mobile computer to communicate with a remote host without any physical connection. Hence, policemen can use it to inquire any information in a remote host and obtain an immediate response. Managers can also handle the latest condition in his or her company by using a mobile workstation. The technique presented in this paper can be applied also to other radio data communication for navigation and to military operations. Since Taiwan is an island with relatively high mountains and there is practically no FCC regulation, this project supported by **Industrial Technology Research Institute (ITRI)**, was to test the radio data communication feasibility using the newly available MRT facility.

Some average sky noises such as the atmospheric noise, the galactic noise, and the water vapor described in [1] exist everywhere. In addition to the white noise, the thermal noise and shot noise also affect the communication error rate of a mobile workstation. In order to overcome the interference from these noises, a transmission protocol and a mixed coding system are developed in our project. After several modifications, the mobile workstation was successfully built and tested in the summer of 1990.

Section II of this paper describes the system architecture and the communication protocol. The operation and coding scheme of the mobile workstation is presented in section III. Some implementation experiences are discussed in section IV. Finally, section V gives a conclusion.

II. System architecture

The system architecture is shown in Figure 1. A remote host is served as a **file server** that provides abundant information to users. The inquiry of mobile workstation is modulated by a modem and transmitted by the MRT. The modulated signal will be delivered by Taiwan telephone network system to the file server. There are many **cellular sections** in the network system, and each section has various re-locatable and reusable channels. Hence, a communication may be connected several times by the network system when the automobile runs across many cellular sections. A mobile base station consists of a radio receiver, a transmitter, an antenna, and a monitor equipment. They are used to transform the radio signal to the signal compatible to the telephone system and vice versa. The mobile base station is controlled by the mobile control station. The another end of cellular mobile telephone system is a mobile telephone exchanger which comprises an interface to the long-distance call network. The inquired information is sent back using the same path.

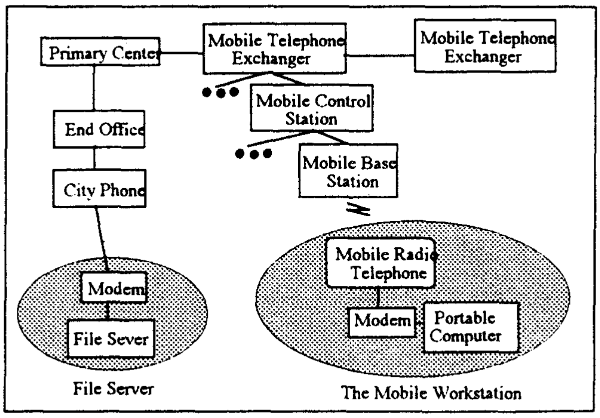

Figure 1. *The communication system for the mobile workstation.*

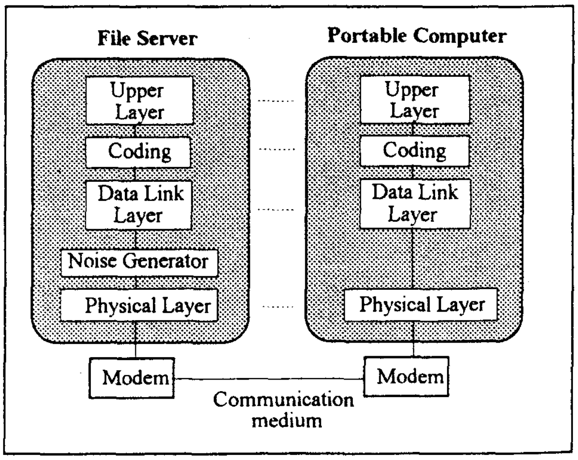

Figure 2. *The system model.*

The model for this communication system is illustrated in Figure 2. We break the model into four layers. The physical layer deals with the mechanical, electrical and procedural interfaces. The main task of the data-link layer is to take a raw transmission facility and transform it into a line that appears free of transmission errors to the coding layer [6]. Hence, the flow control and the error handling are provided by this layer. During the test phase, a **noise generator** is inserted between the physical layer and the data-link layer in the file server. The objective for this noise generator is to simulate the noise interference in the communication medium. In addition, the coding layer is used as a guard for detecting and correcting errors of the received data, and for defending the secrecy of transmitted data. The upper layer involves all functions in the transport layer, session layer, presentation layer, and application layer of the **ISO Open Systems Interconnection (OSI)** reference model.

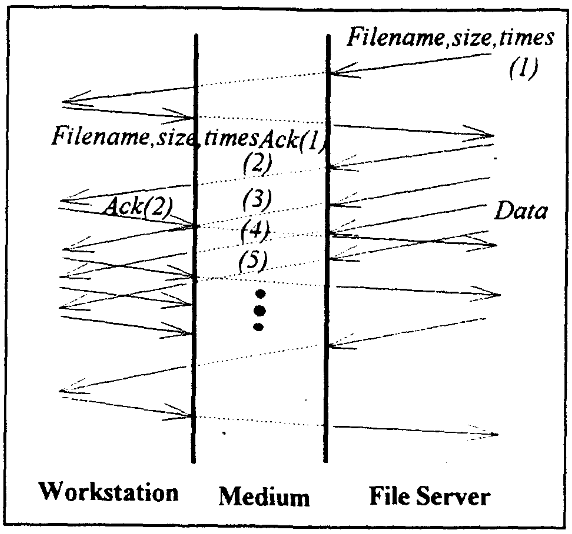

Figure 3. *The file transmission Protocol.*

There are many existent protocols for a noisy channel, for example the **stop-and-wait protocol**, the **sliding window protocol using go back n**, and the **sliding window protocol using selective repeat** [6]. Because of the high error rate in the radio communication, and the low modem data rate, the maximum length of data field is set to 128 bytes in this project. Moreover, the two former protocols have lower performance than the latter, hence the sliding window protocol with selective repeat is adopted.

Figure 3 shows a file transmission sequence from the file server to a mobile workstation. After having received the inquired information from the workstation, the server first retrieves the file information and calculates its transmission time. Then, the server transmits the filename, file size and transmission time to the workstation. Because of the higher error rate, this important header should be acknowledged from the workstation to confirm it is correctly received. If error occurs, then the header is resent. After the server receives a correct response, it begins to send data frame one by one using the sliding window protocol. While the workstation receives a frame correctly, it sends back an acknowledgement signal together with the sequence number of the received frame. If the frame data is not correct, a non-acknowledgement is sent back. When the server receives a non-acknowledgement or no response within an acknowledgement period, it will transmit the damaged frame again. However, if the limit for re-transmission is reached, the transmission will be terminated.

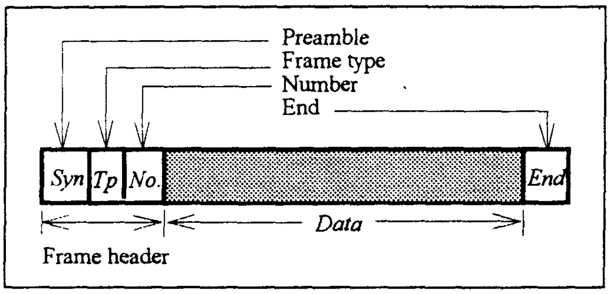

Figure 4. *Data frame format.*

In our project, the data frame format is defined as in Figure 4. There are five fields. The first field is the preamble field which is used to mark the frame boundary. The second field is the type field which is used to distinguish the data frames from the control frames. The third field is a sequence number. A sequence number is attached to each data frame at the transmitter, and the receiver will acknowledge or non-acknowledge each frame according to their sequence number. The fourth field is the data field. The last field is the end delimiter. Because of the noise interference, both the maximum frame length and the time-out period are defined during system startup time. This permits us to fine tune our system according to the working environment.

III. Software operations

In this section, both the protocol specification and the coding scheme for the mobile workstation system will be presented as follows.

• **Program in Estelle**

A protocol specification language **Estelle (Extended State Transition Language)** recommended by ISO is used to specify these operations of our mobile workstation. Figure 5 shows the module relationship of the system model. Three modules and two interconnecting links between them are depicted in this figure. The form of a transition specification in Estelle is shown as follows.

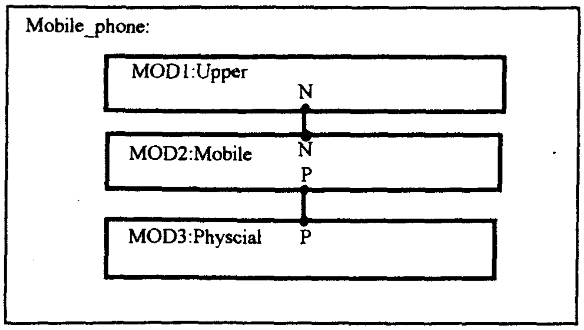

Figure 5. *The module relation of workstation described by ESTELLE.*

Specification *Mobile_workstation;*

```
default individual queue;
{** Default-option **}
timescale seconds;
{ **Time-option **}
Const Lastbit = ...;
{determines packet size}
      MaxSeq = 1;
      RT_Time = ...;
{Re-transmission time}
      Retry = ...;
type Bit = 0..1;
     SeqenceNr = 0..MzxSeq;
     packet =      packet array [0..Lastbit] of Bit;
     FrameKind = (Header, Data, Ack, Nak, Err);
     Frame = packed record
          Kind: FrameKind;
          Seq: seqenceNr;
          Info: Packet;
     end;

Link NAP(User, Provider);
{**Channel definition**}
     by User: DATA_CONFIRM(N_Data: Packet);
     by Provider: DATA_INDICATION(N_Data:
Packet);

Link PAP(User, Provider);
     by User:
          S_REQUEST(P_Data: Frame);
     by Provider:
          R_RESPONSE(P_Data: Frame);

module UpperLayer process;
     {**Module definitions**}
     ip N: NAP(User) common queue;
end;
module Mobile process;
     ip N: NAP(Provider) common queue;
       P:PAP(User) individual queue;
end;
module PhysicalLayer process;
     ip P: PAP(Provider) individual queue;
end;

{** Body definition for modules **}
body UpperBody for UpperLayer; external;
body PhysicalBody for PhysicalLayer; external;
body MobileBody for Mobile;
     var R: Packet;
         S1, S2: Frame;
         NextFrameToSend, FrameReceived, RT:
seqenceNr;
     state Idle, Active;
{**state of physical layer**}
     procedure Exit(); external;
     procedure Inc(var k: seqenceNr);
      begin
          if k < MaxSeq
          then k := k+1
          else k:= 0
      end;

      initialize;
      to Idle
         begin
             NextFrameToSend := 0;
             FrameReceived := 0;
         end;

{**transition declaration of the par process**}
repeat
  {** packet from upper layer is made to frames**}
  {** then sent to the physical layer when window
          is not empty**}
     from Idle to Active
          when N.DATA_INDICATION
            begin
               S1.Kind := Data;
               S1.Seq := extFrameToSend;
               S1.Info := N_Data;
               Rt := 0;
               output P.S_REQUEST(S1);
            end;

     from Active to Active
        when P.R_RESPONSE
            {**Acknowledgement is received**}
            if P_Data.Kind = Ack then
                begin
                     Inc(NextFrameToSend);
                end;

     {**frames incorrectly receive then sent a
          Nack back**}
     if P_Data.Kind = Err or P_Data.Seq <>
                                   FrameReceived
then
          begin
               S2.Kind := Nak;
               S2.Ack := FrameReceived;
               output P.S_REQUEST(S2);
               Inc(Rt);
               If Rt = Retry then Exit();
          end;

     {**response using the received header and
               a Ack **}
     if P_Data.Kind = Header then
          begin
               S1.Kind := Ack;
               S1.Seq := NextFrameToSend;
               S1.Info := P_Data.Info;
               Rt := 0;
               output P.S_REQUEST(S1);
          end;
     {**asking the upper layer to retransmit the
               damaged frame **}
     {**when received a Nack**}
     if P_Data.Kind = Nack then
          begin
```

```
                S1.Kind := Data;
                S1.Seq := P_Data.Seq;
                S1.Info := buffer;
                Rt := 0;
                output P.S_REQUEST(S1);
            end;

    from Active to Idle
      when P.R_RESPONSE
       { **Data frames correctly receive, then pass
            them to upper layer**}
      {**response a acknowledgement to the
            physical layer**}
      if P_Data.Kind = Data and P_Data.Seq =
            FrameReceived then
            begin
                S2.Kind := Ack;
                S2.Ack := P_Data.Seq
                output P.S_REQUEST(S2);
                R := P_Data.Info;
                output .DATA_CONFIRM(R);
                Inc(FrameReceived)
            end;
until doomsday
end;  {** of the ParBody **}

modvar Mod1: NetworkLayer;
       Mod2: Par;
       Mod3: PhysicalLayer;
initialize
  begin
    init Mod1 with NetworkBody;
    init Mod2 with ParBody;
    init Mod3 with PhysicalBody;
    connect Mod1.N to Mod2.N;
    connect Mod2.P to Mod3.P;
  end;
end          {** End of specification **}
```

- **Secret Error Correcting Codes using Block Chaining (SECC-BCC)**

In the past, the **algebraic-code** is widely used to correct the random errors and the burst errors in communication. However, it does not provide the function of **encrypting** and **authentication**. In 1978, McEliece develops a **public key crypto-system** by using the Goppa code to provide the data secrecy and the error correction [2]. In 1988, Hwang proposes a SECC-BCC system that offers the data secrecy, the error correction and the authentication in a one-step process [3]. The block diagram of SECC-BCC system is shown in Figure 6. The definition of each component in the SECC-BCC system is as follows:

f ≡ an inverse-able nonlinear function
G ≡ a generator matrix of (n, k)
g ≡ a nonlinear expanding function
D ≡ decoding operations
δ ≡ one cycle delay buffer.
$\oplus$ ≡ the exclusive-OR.

The sequence of coding in the SECC-BC is:

$$C_1 = f(M_1)G + Z_1$$
$$C_2 = f(M_2 + X_1)G + Z_2 \quad \text{where } X_1 = f(M_1),\ Z_2 = g(X_1)$$
$$C_3 = f(M_3 + X_2)G + Z_3 \quad \text{where } X_2 = f(M_2 + X_1),\ Z_3 = g(X_2)$$
$$\cdots\cdots$$
$$C_m = f(M_m + X_{m-1})G + Z_m \quad \text{where } X_{m-1} = f(M_{m-1}),\ Z_m = g(X_{m-1})$$

The sequence of decoding in the SECC-BC is:

$$D(C_1') = X_1 = f(M_1), f^{-1}(X_1) = M_1$$
$$D(C_2' + g(X_1)) = X_2 = f(M_2 + X_1), f^{-1}(X_2) + X_1 = M_2$$
$$\cdots\cdots$$
$$D(C_m' + g(X_{m-1})) = X_m = f(M_m + X_{m-1}), f^{-1}(X_m) + X_{m-1} = M_m$$

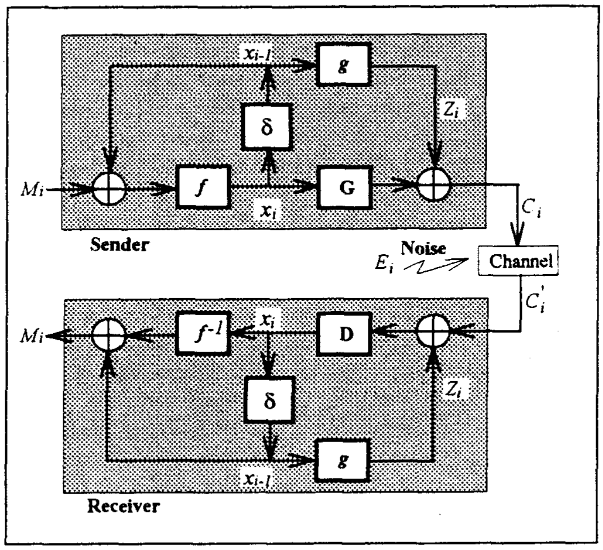

Figure 6. *The SECC-BCC system.*

The error pattern in MRT can be generally divided into two categories: random error and burst error. The Bose, Chaudhuri, and Hocquenghem (BCH) codes form a large class of powerful random error-correcting cyclic codes [4]. With the interleaving technique, it can be also used to correct the burst errors. The error rate in MRT is between 10^{-2} and 10^{-3}. Moreover the majority of error pattern in MRT is the burst error. Hence, the (31,16,3) BCH code with interleaving technique is used to design the generator matrix G. As for the inverse-able nonlinear function, it can be constructed by modifying the LUCIFER system designed by Feistel in 1973 [5].

IV. Implementation.

Before this project, we do not have any experience in the MRT. Moreover, the information provided by Taiwan telephone and telegraph office is limited. Therefore, what will happen in the mobile workstation is difficult to estimate and predict at its beginning. For example, the experiments for measuring error rate and error pattern can not be done as scheduled, because the monthly charge for MRT is much higher than our budget. This causes many unnecessary modifications later on.

At the beginning of implementation, we select the random error as the major error pattern of the MRT communication system, and use the error rate data published overseas to design our system. After the prototype is completed, we do some experiments to evaluate the characteristics of each communication segment. The wire segment is evaluated first, and our experiment shows that there is almost error free in the wire communication segment. In order to evaluate the error correcting capability of our prototype, a noise generator with the random error pattern is inserted between the data-link layer and the physical layer in the file server, and the system works correctly. When we test our system with the MRT, the result doesn't show as expected, because most errors are burst errors in the communication medium.

In April of 1990, a functional MRT was finally setup. We found the bigger file could not be sent successfully, and the re-transmitting procedure was not robust enough to tolerate burst type error. Several modifications on the protocol and on the coding scheme were made. There is a tradeoff between performance and the robustness that we have to deal with. In addition, modem reliability was also one of the issue we had to take into consideration. Finally after we adjust our protocol and error correcting scheme to handle the encountered error pattern, we made our mobile workstation working successfully along the highway. Yet at some spots in the ITRI communication lab, it could not handle large file. Only after having moved the workstation a little farther from the lab, it functioned properly. We believed that the **Electromagnetic Interference (EMI)** in the lab caused problem. In this experiment, the mobile workstation consists of a Motorola 4W MRT, an Intel 80286 laptop computer, and a 2400 bps baud rate modem. The occurrence of re-transmission was also measured; it was 1/60 with the frame size set to 128 bytes.

V. Conclusion.

In the sprout of MRT business in Taiwan, we implement a mobile workstation to provide the real-time inquiry service wherever the workstation is. During the implementation, many interference sources are found in our surrounding. It suggests us that the management for radio interference should be strengthened. The mobile workstation presented in this paper provides the capability of error-detection, correction for few error bits, and of data secrecy. Since the price of a mobile workstation is decreasing, we believe their usage will be more universal in the future.

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