Real-Time Embedded Systems

CpE-450 Spring 07

Class 12

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Case Study 3: The Cellular Phone

~1990 3W Analog AMPS

~1994 600 mW AMPS/TDMA

~1996 600 mW AMPS/TDMA

~2001 600 mW AMPS/TDMA

~1990 3W Analog AMPS
Case Study 4:
The Cellular Phone

~1990 3W Analog AMPS

~1994 600 mW Analog AMPS

~1996 600 mW AMPS/TDMA

Nokia 6162
850 MHz Analog/
1900 MHz TDMA

~2001 600 mW AMPS/TDMA
Transceiver Anatomy 101

User Interface
Transceiver Anatomy 102
Lessons from Anatomy

Shield well, shield often

Heat producers at top (heat rises)
Transmitter near antenna
Battery connections near transmitter
Separate Synthesizer
Analog Digital Separation
Linear signal flows

Channel control

Receive

Transmit

μP/DSP

TX

DPX

PLL

VCO

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Clock Generation

19.44 MHz Master Clock -> Divide by 648 -> 30 kHz Synthesizer Reference -> 800, 1900 MHz Synthesizer

Divide by 800

Divide by 2430 -> 8 kHz speech sample clock -> Speech A/D, D/A

24.3 kHz Channel Symbol rate -> Modulator/Demodulator
IS-136 Channel Structure (Downlink)

40 milliseconds

Slot 1 | Slot 2 | Slot 3 | Slot 4 | Slot 5 | Slot 6

- **sync** (14 symbols)
- **SAACH** (6 symbols)
- **Data** (65 symbols)
- **DVCC** (6 symbols)
- **Data** (65 symbols)
- **DL+** (6 symbols)

(162 symbols/slot * 2 bits/symbol) * 6 slots/frame → 1944 bits/frame

1944 bits/frame * 25 frames/sec → 48.6 kb/s
IS-136 Channel Structure (Downlink)

(130 data symbols/slot * 2 bits/symbol) * 2 slots/frame \(\Rightarrow\) 520 data bits/frame

520 data bits/frame * 25 frames/sec \(\Rightarrow\) 13 kb/s (data)
IS-136 Transmitter/Receiver Structure

Base station

Network I/F, A/D -> Speech Coder -> Channel Coder

Network I/F, A/D -> Speech Coder -> Channel Coder

Network I/F, A/D -> Speech Coder -> Channel Coder

8 kb/s

Speech Coder -> Channel Coder

13 kb/s

MUX -> D/A -> Modulator -> RF

48.6 kb/s

9.6 kb/s

RF -> A/D -> Demod

Channel Decoder

Speech Decoder

D/A -> Audio

System Clock

Timing Recovery

Timing Recovery

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Handset Receiver Software Structure

```c
main()
{
    initialize();
    while(1)
    {
        sleep();
        switch(alarm)
        {
            case 40ms:
                demod_frame(!FB#);
                decode_frame(!FB#);
                if(detect_signal(!FB#))
                    act_on_sig();
                adjust_timing();
                decode_speech(!FB#,!SB#,P);
                break;
            case user:
                x=decode_command(UIB);
                act_on_command(x);
                break;
        }
    }
}
```

```c
bit frame_buffer_nr=0;

40ms_frame_int()
{
    read_a_frame(frame_buffer_nr++);
    wake_BG(40ms);
}
```

```c
bit speech_buffer_nr=0;
int position;

speech_DA_int()
{
    write_DA(speech_buffer_nr,position);
    if(position>length)
    {
        SB#++;
        position=0;
    }
}
```

```c
char UI_buffer_nr[N];

user_int()
{
    scan_UI(UI_buffer_nr++);
    wake_BG(user);
}
```
Timing adjustment

Base station

Handset

A/D \rightarrow TX \rightarrow D/A

Fixed Timing

Network Clock Standard

Recovered Timing

D/A \rightarrow RX \rightarrow A/D

Downlink

A/D \rightarrow RX \rightarrow D/A

Recovered Timing

Handset Clock Standard

Fixed Timing

D/A \rightarrow TX \rightarrow A/D

Uplink

Timing adjustment

The receiver input and output clocks can vary with respect to each other.

Base station

Handset

Downlink

Uplink
Timing adjustment

- **Base station**
  - A/D → TX → D/A
  - Fixed Timing
  - Network Clock Standard
  - Recovered Timing
  - D/A → RX → A/D

- **Handset**
  - A/D → RX → D/A
  - Recovered Timing
  - Handset Clock Standard
  - Fixed Timing
  - D/A → TX → A/D

These clocks cannot be varied.
Timing adjustment in digital receiver

Desired channel response
Timing adjustment in digital receiver

Desired channel response

4X oversampled channel response
Timing adjustment in digital receiver

Desired channel response

4X oversampled channel response

4X oversampled channel response separated into 4 different filters
Timing adjustment in digital receiver

- Desired channel response

- 4X oversampled channel response

- 4X oversampled channel response separated into 4 different filters

- Channel response from 1 sample delay filter
Timing adjustment in digital receiver

A/D Converter → Digital Channel Filter → Filter Coefficients → Select 1 of N → Timing Recovery
Digital output buffering
References


Homework #8

- Project due next week
- Final will be posted next week, due 1 week later