Design Examples and Case Studies of Program Modeling and Programming with RTOS-2:

Lesson-3

CASE STUDY OF AN EMBEDDED SYSTEM FOR SMART CARD

1. Smart Card System Requirements

Purpose

- Enabling authentication and verification of card and card holder by a host
- Enabling GUI at host machine to interact with the card holder/user for the required transactions, for example, financial transactions with a bank or credit card transactions.

Inputs

- Received header and messages at IO port *Port_IO* from host through the antenna

Internal Signals, Events and Notifications

- On power up, radiation-powered charge-pump supply of the card activated and a *signal* to start the system boot program at resetTask
- Card start *requestHeader* message to task_ReadPort from resetTask
- Host authentication request *requestStart* message to task_ReadPort from resetTask to enable requests for Port_IO

Internal Signals, Events and Notifications

- *UserPW* verification message (notification) through Port_IO from host
- Card application close request *requestApplClose* message to Port_IO

Outputs

- Transmitted headers and messages at Port_IO through antenna

Control panel

- No control panel is at the card. The control panel and GUIs activate at the host machine (for example, at ATM or credit card reader)

Functions of the system

- The card inserts at a host machine.
- The radiations from the host activate a charge pump at the card.
- The charge pump powers the SoC circuit consisting of card processor, memory, timer, interrupt handler and IO port, Port_IO.
- On power up, system reset signals resetTask to start.
- The resetTask sends the messages *requestHeader* and *requestStart* for waiting task task_ReadPort.

Functions of the system…

- task_ReadPort sends requests for host identification and reads through the Port_IO the host-identification message and request for card identification.

Functions of the system…

- task_PW sends through Port_IO the requested card identification after system receives the host identity through Port_IO.
- task_Appl then runs required API. The *requestApplClose* message closes the application.

Functions of the system…

- The card can now be withdrawn
- All transactions between card-holder/user now takes place through GUIs using at the host control panel (screen or touch screen or LCD display panel).

Design metrics

- Power Source and Dissipation: Radiation powered contact less
- Code size: optimum. card system memory needs should not exceed 64 kB memory.

Design metrics

- Limited use of data types; multidimensional arrays, long 64-bit integer and floating points and very limited use of the error handlers, exceptions, signals, serialization, debugging and profiling.
- File system(s): Three-layered file system for data.

Design metrics…

- *File management:* There is either a fixed length file management or a variable file length management with each file with a predefined offset.
- *Microcontroller hardware*: Generates distinct coded physical addresses for the program and data logical addresses. Protected once writable memory space

Design metrics…

- Validity: System is embedded with expiry date, after which the card authorization through the hosts disables.
- *Extendibility*: The system expiry date is extendable by transactions and authorization of master control unit (for example, bank servee).

Design metrics…

- Performance: Less than 1s for transferring control from the card to host machine.
- Process Deadlines: None.
- User Interfaces: At host machine, graphic at LCD or touch screen display on LCD and commands for card holder (card user) transactions.

Design metrics…

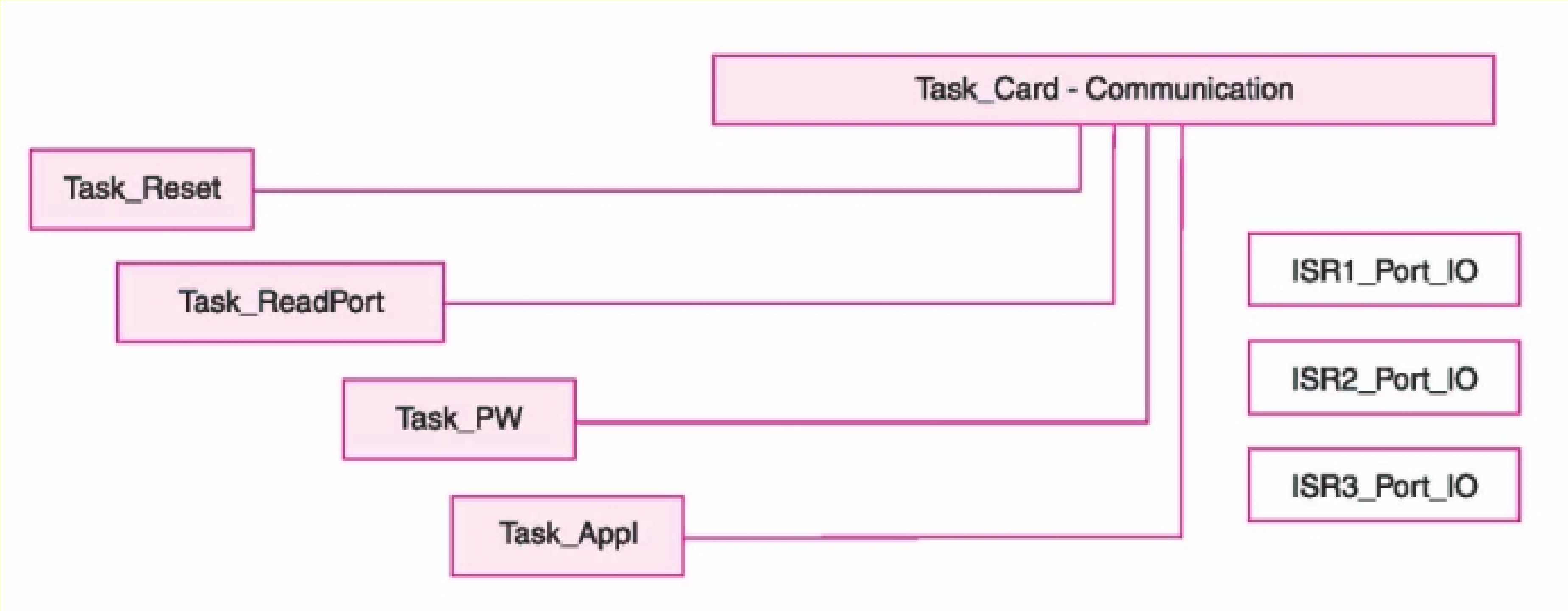
- Engineering Cost: US$ 50000 (assumed)
- Manufacturing Cost: US$ 1 (assumed)

Test and validation conditions

- Tested on different host machine versions for fail proof card-host communication

2. Classes and class diagram

Class diagram



Classes

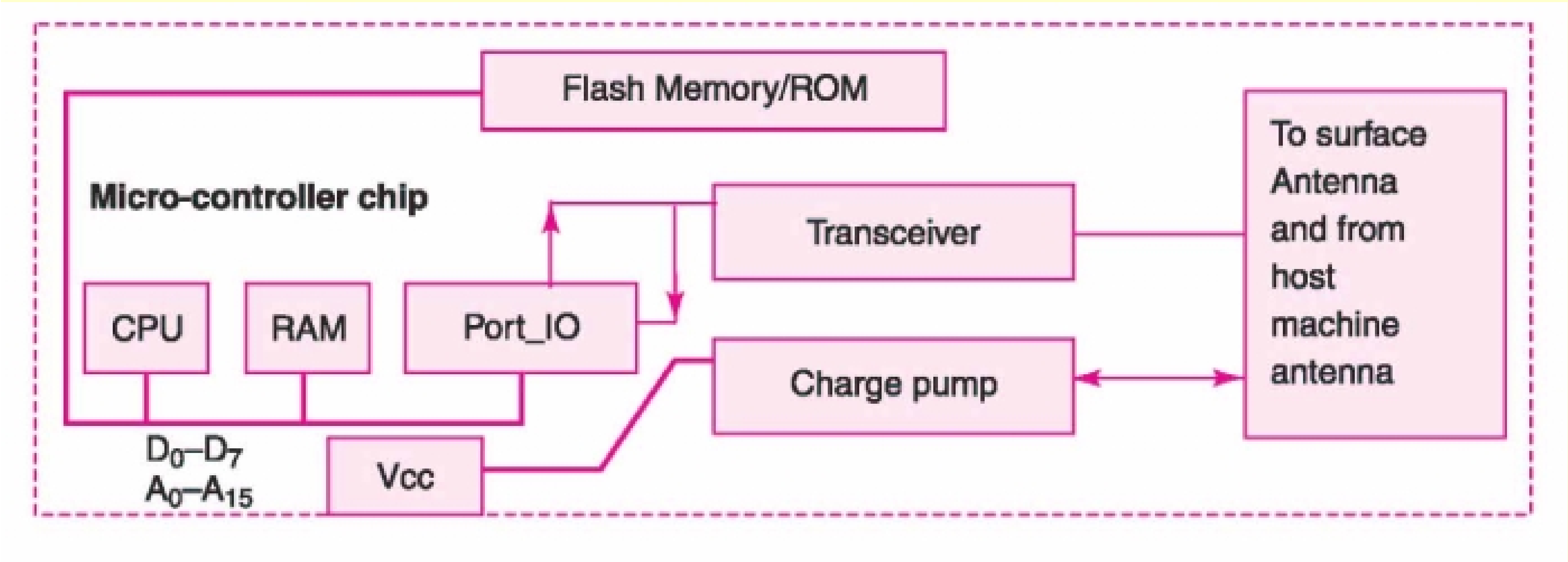
- Task_CardCommunication is an abstract class from which extended to class (es) derive to read port and authenticate.
- The tasks (objects) are the instances of the classes Task_Appl, Task_Reset, Task_ReadPort and Task_PW.
- ISR1_Port_IO, ISR2_Port_IO and ISR3_Port_IO are interfaces to the tasks

Other Classes

- Classes for the network, sockets, connections, datagrams, character-input output and streams, security management, digital-certification, symmetric and asymmetric keys-based cryptography and digital signatures

3. Hardware Architecture

Smart card hardware



Smart Card Hardware

- A plastic card in ISO standard dimensions, 85.60 mm x 53.98 x 0.80 mm. It is an embedded SoC (System-On-Chip). [ISO standards - ISO7816 (1 to 4) for host-machine contact based card and ISO14443 (Part A or B) for the contact-less cards.]

Smart Card Hardware …

- Microcontroller MC68HC11D0 or PIC16C84 or a smart card processor Philips Smart XA or an ASIP Processor. Needs 8 kB+ internal RAM and 32 kB EPROM and 2/3 wire protected memory.
- CPU special features, for example, a security lock

Smart Card Hardware …

- CPU locks certain section of memory - protect 1 kB or more data from modification and access by any external source or instruction outside that memory
- Other way of protecting - CPU access through the physical addresses, which are different from logical address used in the program.

Smart Card Hardware …

- Standard ROM 8 kB for usual or 64 kB when using advanced cryptographic features
- Full or part of ROM bus activates take place after a security check only.

Smart Card Hardware …

ROM Contains:

i. Fabrication key and Personalisation key (after insertion of this key, RTOS and application use only the logical addresses)

ii. RTOS codes

iii. Application codes

iv. Utilisation lock

Smart Card Hardware …

- **EEPROM or Flash** scalable – only needed part unlocks when storing P.I.N., unlocking P.I.N., access condition, card-user data, post activation application run generated non-volatile data, invalidation lock to invalidate card after the expiry date or server instruction

Smart Card Hardware …

- RAM – run time temporary variables
- Chip-supply system using charge pump
- I/O system

4. Software Architecture

Smart Card Software

- Needs cryptographic software, needs special features in its operating system over and above the MS DOS or UNIX system features.

Smart Card Software …

- Protected environment -OS stored in the protected part of ROM.
- A restricted run-time environment.
- OS, every method, class and run time library should be scalable.

Smart Card Software …

- Optimum Code-size
- Limited use of data types; multidimensional arrays, long 64-bit integer and floating points and very limited use of the error handlers, exceptions, signals, serialisation, debugging and profiling

Smart Card Software …

- Three-layered file system for the data
- *master file* to store all file headers (file status, access conditions and the file lock)

Smart Card Software …

- A header means file status, access conditions and the file lock.
- Dedicated file— second file to hold a file grouping and headers of the immediate successor
- Elementary file — third file to hold the file header and its file data.

Smart Card Software …

- Either a fixed length file management or a variable file length management with each file with a predefined offset.

Smart Card Software in Java

- Java Card™, EmbeddedJava or J2ME (Java 2 Micro Edition) JVM has thread scheduler built in.
- Java provides the features to support (*i*) security using class java.lang.SecurityManager), (ii) cryptographic needs (package java.security*).

5. SmartOS RTOS used as alternative to MUCOS

Smart Card OS

- SmartOS─ assumed hypothetical OS in this example, as RTOS in the card.
- Use for understanding purposes identical to MUCOS but actual SmartOS has to be different from MUCOS.
- Its file structure is different, though it has MUCOS like IPCs and ECBs.

SmartOS..

- function unsigned char [ ] SmartOSEncrypt (unsigned char *applStr, *EnType type*) encrypts as per encryption method, *EnType* = "RSA" or "DES" algorithm chosen and returns the encrypted string

SmartOS …

- function unsigned char [ ] SmartOSDecrypt (unsigned char *Str, DeType *type*) encrypts as per deciphering method, DeType = "RSA" or "DES" algorithm chosen and returns the deciphered string.

SmartOS …

- SmartOSEncrypt and SmartOSDecrypt execute after verifying the access conditions from the data files that store the keys, PIN (Personal Identification Number) and password.

6. Tasks and their priority, action and IPCs

resetTask

- Priority ─ 1
- Action─ Initiates system timer ticks, creates tasks, sends initial messages and suspends itself.
- IPC pending:
- IPC posted: SigReset, MsgQStart
- String Output: *request-Header*; *request-Start*

task_ReadPort

- Priority ─ 2
- Action─ Wait for resetTask suspension, sends the queue messages and receives the messages. Starts the application and seeks closure permission for closing the application
- IPC pending: SigReset, MsgQStart, MsgQPW,
- MsgQAppl, MsgQAppl-Close
- IPC posted: SemPW
- Output: *request-password*, request-*Appl*, request-ApplClose

task_PW

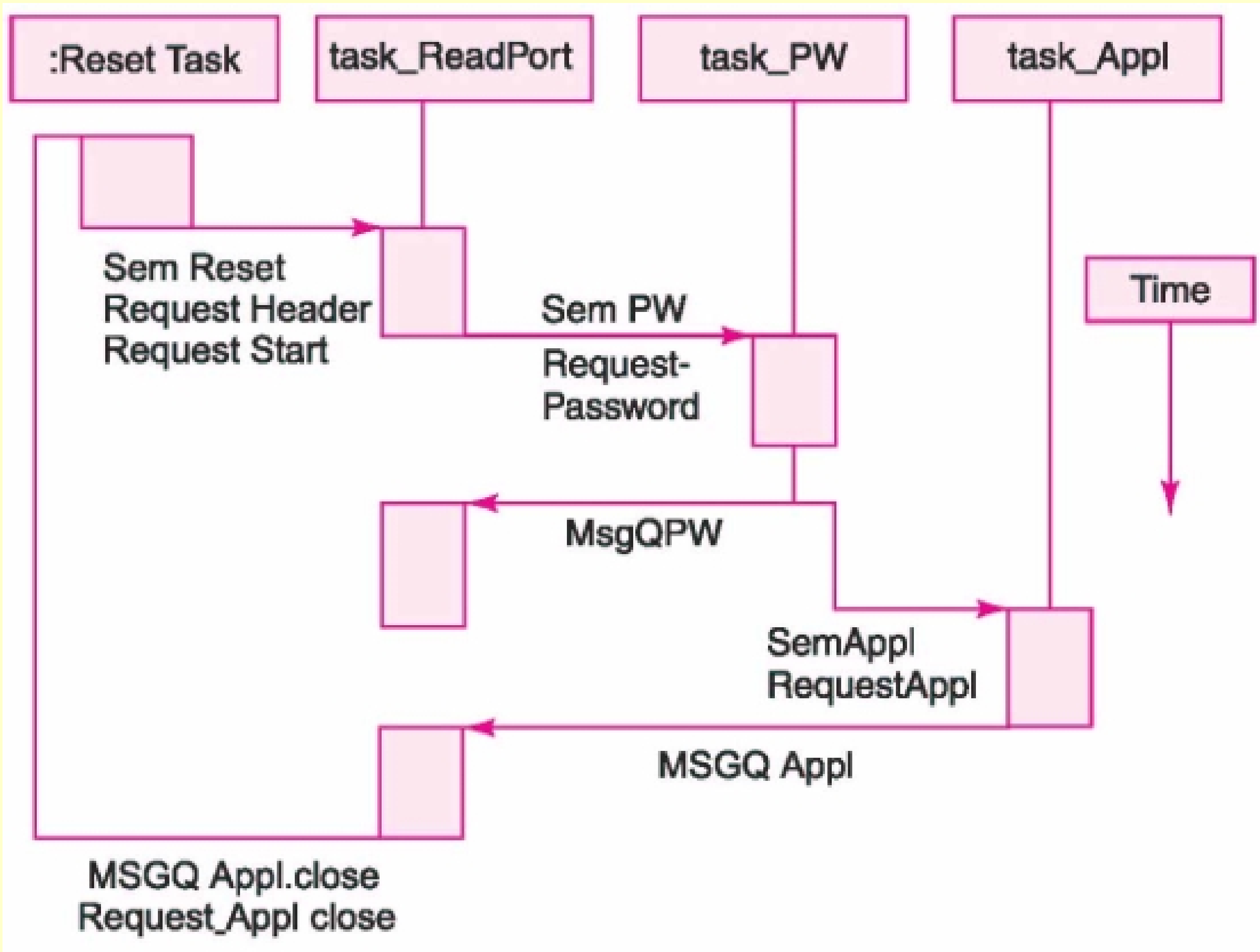
- Priority — 3
- Action— Sends request for password on verification of host when SemPW = 1
- IPC pending: SemPW
- IPC posted: *MsgQPW*
- Input: request-Password

task_Appl

- Priority ─ 8
- Action─ when SemPW = 1, runs the application program
- IPC pending: SemAppl
- IPC posted: *MsgQAppl*

7. Multiple tasks and their synchronization model

tasks and their synchronization model



8. Coding using SmartOS

Coding using VxWorks Adapted to OSEK-OS Features

- Refer Example 12.4 in Section 12.4.5 Note: At each step, explanation for the set of statements given there.

Summary

We learnt

- Smart Card hardware and software
- Code design given using the a hypothetical RTOS, SmartOS, which has MUCOS features plus the embedded system required cryptographic features and file security, access conditions and restricted access permissions during code run.

End of Lesson-3 of chapter 12 on

CASE STUDY OF AN EMBEDDED SYSTEM FOR SMART CARD