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Tancher Garden Deep Integration – the modular approach in system integration solutions based on wireless mobile terminals.

Summary

Based on the experience gained for the last decade, R&D company analyses existing approaches in system integration tasks solutions based on wireless terminals. The novel approach proposed allows one to get significant advantages when functionality of the terminals is strictly limited. Some practical examples are described.

Introduction

Not long ago any portable device with functionally just a little better than that of a simple calculator was impressive for the market only by the fact of it's appearance on the shelves. Since that time many things have changed. A wide range of gadgets appeared on the market covering a huge variety of functions staring from remote controls and ending up with PDAs very close to PCs in functionality. Mobile devices entered daily life which leads to a need to integrate them seamlessly into all the human activity areas. WiFi, Bluetooth, cellular networks; with a constant market price reduction all these technologies have become a usual instrument for everyone.

Every mobile device is created to solve a set of predefined tasks. From the client's (who orders the design) or end user's point of view it is very important that the device solves the necessary tasks with minimal expenses. In this case we do not consider the problem of the user characteristics or the device status. Some times the design itself or the product positioning effects the price.

Let's introduce a criterion reflecting the effectiveness of the tasks solution (both user and integration tasks) based on the mobile devices.

With a certain confidence in a number of units sold on the market (during the whole life time of the device) the design and development expenses can be expressed as a part of the device cost. Let $P_D = P_{SW} + P_{HW}$ – be a development cost, including high level solutions that we place on software design P_{SW} plus hardware design cost P_{HW} including prototyping and mass production launch expenses (test equipment, fixtures, certifications, etc. not including the component cost). P_S – is a unit cost according to BOM (Bill Of Materials), including labor cost, manufacturer's margin and licensing fees, P_{SM} - sales and marketing expenses (the expenses to bring the product to the market) and N – is a number of units sold. The unit price (street) will be:

$$P = \frac{(P_D + P_{SM})}{N} + P_S$$

Design and development expenses P_D typically vary from several thousand to several million USD. Sales and marketing expenses are also heavy – for retail market they can reach tens of million dollars.

The component cost usually does not exceed $1000. If *N* is small enough, the unit price is defined by development and marketing expenses. When talking about small batches we usually deal with specialized solutions. In this case we can consider sales and marketing expenses being negligible comparing to the development cost. If *N* is large, say, for the cell phones, than the development expenses are not really effecting the end user price, nevertheless promo expenses shall be pretty much under control.

Let's introduce a variable reflecting the level of usage of the functions embedded into the device. It is reasonable to assume that this variable is defined by coefficient ξ of the averaged device capacities loading – processor, memory, ports. The effective price of the device will be:

$$E = \frac{P}{\xi}$$

We will measure the effectiveness of the solution by means of this criterion – the effective price of the devices being a base block of the system, or the effective price of the system node.

As competition grows along with a number of device manufacturers, the design and development timelines or time to market becomes critical. If 10-15 years ago this period was about several years than now this parameter is reduced to several months. The products are getting old very fast.

Let's define two types of the mobile devices

1. Universal devices. Those terminals are not prescribed to solve any specific problem. They are designed to cover a wide range of functions.

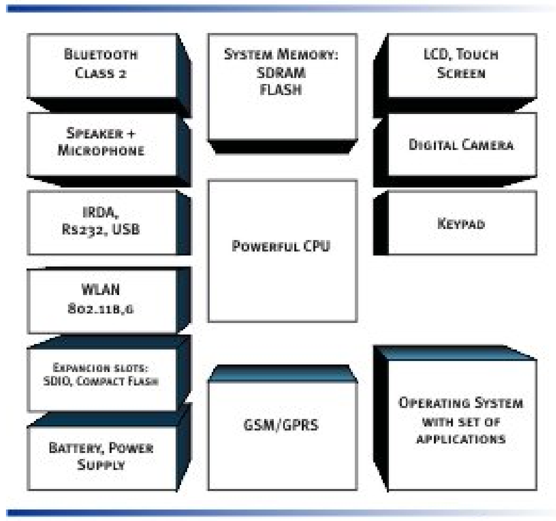
2. Specialized devices. Those devices are designed to solve specific problems. The functionality of these devices is usually limited or they have functions that average user does not need, such as bar-code readers, payment terminals, medical equipment, etc.

Let's consider the **universal devices (1).** Covering a wide spectrum of functions those devices are usually made for retail market or for the trivial integration tasks.

The device with maximum functionality embedding all the latest technological achievements usually belongs to the high price niche. Here we deal with smart phones or advanced PDA models.

The typical structure of the universal device in the high price category is presented on Pic. 1.

THE STRUCTURE OF MOBILE TERMINAL



PICTURE 1

In this device user has everything that he or she could potentially need in his life: all possible communication interfaces, large memory, extension cards support, high resolution LCD, embedded camera and microphone as well as operation system with wide range of applications including office apps, Internet apps and games. There is a lot of example of such devices on the market: HTC products, palmOne, Blackberry, Nokia 90 series – all these devices are in high price niche.

The lower price niche devices are also of the same ideology regardless lower quality LCD, less memory and less options in operation system. From the user standpoint the idea is the same. The devices is prescribed to cover as many users as possible. The examples of that kind of the devices can be all mid and low end models of the same manufacturers (see above) as well as most of the cell phones.

In case of universal devices every end user always has to evaluate the effectiveness E himself. Estimating the need in the main functions proposed by the supplier ξ one must remember that he pays not only for the design and development but also covers significant expenses to get the product to the market. This is why the users who buy gadgets first (progressive buyers) always pay more than later adepts. To that, the more expensive the device (the more universal the device) – the faster it's price goes down with time – to promote super novel gadgets is always more expensive than to sell usual stuff.

We shall notice that for equal ξ s and different prices per unit the buyer's choices is also effected by the design and brand. Usually it doesn't matter who actually produced the device – say HTC produces devices under its own brand as well as under the others' (Fujitsu-Siemens, HP, etc.)

Speaking about **specialized devices (2)** and their orientation on strictly limited functionality, there is much less of those on the market (*N*). They are manufactured by much less batches and for specific client. When describing integration solutions in general we shall note the following approaches:

1. Ready to use solutions

The typical situation looks as follows. A customer needs a common solution and the suppliers can propose already developed devices with appropriate software. By that moment of time the solution provider has already paid for the development P_D and has covered some expenses on promotion P_{SM} (incomparably smaller, though, than in the case of the retail market). The further customer's work is to choose a solution that already exists on the market and meets certain requirements. This approach reveals obvious disadvantages. The specific solution must be more or less universal, that automatically increases the E value. In fact, any developer (or solution provider) is interested in production of the devices that meet wide range of requirements to cover the most part of the potential customers. After some investigations this leads to development of the device that contains a composition of functions needed to cover the whole class of similar tasks. This leads to a lack of functions really needed for specific user and at the same time contains functions that one does not need at all. As a result we get a low value of ξ. To that, equipment manufacturers are trying to use the latest technologies, standards and protocols, often incompatible with predecessors.

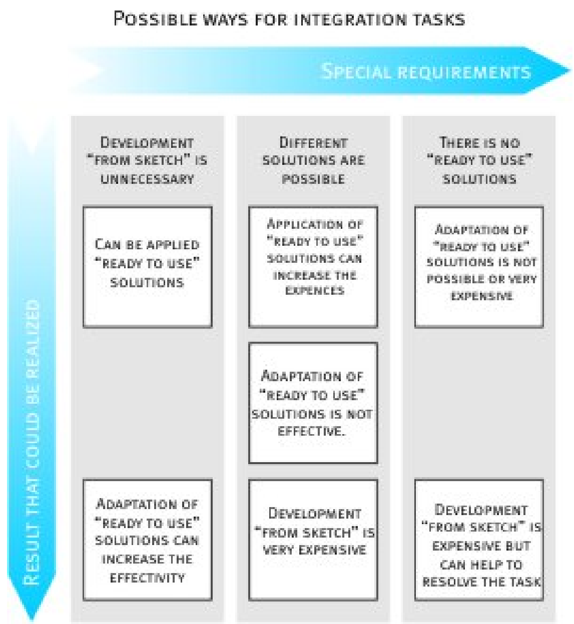
2. Adaptation of "ready to use" solutions.

In many cases, especially regarding innovative or nonstandard approaches, ready to use solutions that completely satisfy customer's needs do not exist on the market. In this case an adaptation of universal devices is applicable. One uses a universal device's computational resources to process the data preliminary transferred on board via external interface. This approach is used very often. It implies development of an extension module and appropriate software. The disadvantage of this approach is that along with the basic device customer gets a number of components that will never be used; in other words, the customer partially overpays for the units' development and for the unnecessary components. Customer also pays for the introduction of the original device to the market P_{SM}. In this case the load level of the unit ξ is also small due to a glut of functions. As a result we get high effective cost of E solution again. The typical example of this approach are educational projects, most of which failed. Without considering methodology deeply, customers are trying to deploy integration solutions that consist of ready to use devices with wireless access (usually the last versions of PDAs), server for the tutor and appropriate software. At the same time in most of the cases, say, high quality screen is not really necessary. Applications on the device don't require so much RAM as for video run as well as heavy office programs are not of a need. To operate this device USB interface is fairly enough. Multimedia facilities can be easily placed on the tutor's computer. Finally, users are forced to use high-end devices for several hundred dollars, where several times lower price devices would suffice. However the market doesn't offer such devices, because it is easier for manufacturers to be oriented on the wide markets and maintain devices' price on the higher level. There is another approach that consists in purchasing out-of-date devices which cost is considerably less due to a obsolescence. However it is extremely difficult to support such solutions, and it is almost impossible to supply the market with more than few hundreds devices.

3. Development of the devices "from sketch".

In case the large amount of units is needed and if the approaches stated above do not work, one has to develop the device "from sketch". This way is undoubtedly the best to reach the highest possible satisfaction of customer's requirements providing the control to the development cost P_D and the cost of BOM P_S from the very beginning. The customer does not pay for the introduction on the market P_{SM} and, given the appropriate task assignment, provides the highest value for the coefficient ξ. However, before starting the project, the customer should evaluate all negative aspects of this approach. First, the development of the devices requires certain investments on the early stages – much earlier than expected product release date. Second, there are some risks related to the task assignment. To achieve the objectives customer should define very accurately the required functions, ergonomics and the period of product operation. Third, the timelines of the development may cause problems. Talking about creation of a completely new device the timelines from start to the final version can be about a year (according to our company's experience regarding special mobile terminal solutions). De-facto, if the customer decides to develop a new device he or she has to act as a venture capitalist, which is usually not planned. In this case the customer starts to think of getting profit from selling the device on the other markets or selling intellectual property and/or technologies' licensing etc. Herein additional marketing risks occur. Forth problem reflects a deficit of the device development services. In the whole world there are no more than a hundred of dedicated companies – design-centers. The market of such services is quite fuzzy and a great job is to be done to choose a design center. This market shows the situation of a supply deficit along with a demand deficit that leads to a great uncertainty. Mid-size companies are interested in substantial profit rates that automatically increases development cost, meanwhile large design-centers are affiliated with large companies – electronics manufacturers (Nokia, Motorola, Samsung) and first of all they process the orders of the parent company. As a result they are not enthusiastic about "small" orders and even if the order is "large" your project has low priority that leads to longer timelines (several years or more even for uncomplicated devices). Sometimes marketing companies keep their own development staff which is most often ineffective economically as such department requires specific complex management and the marketing company has to bear all costs related to developers' salaries even when the roadmap is empty.

Summarizing, it can be said that when customer comes to a need of proper equipment, he or she has to solve a difficult optimization task choosing from a quite small amount of variants.
The choice dilemma can be illustrated as follows



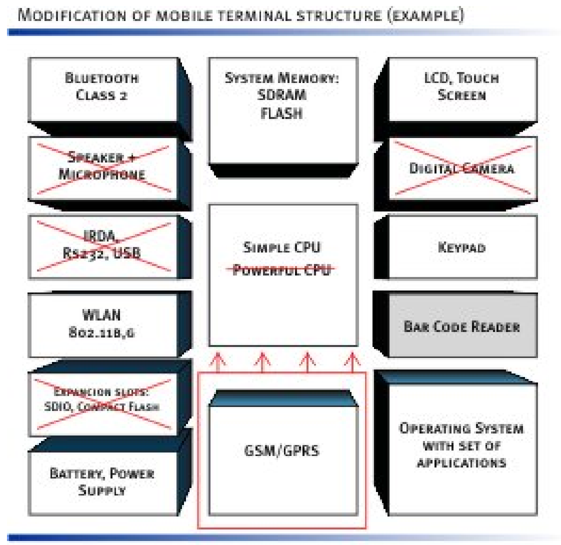
Picture 2

If we are solving a standard task, the solution of which can be applied not only for the situation involved but also can be required by other customers, the situation looks acceptable. But in case of a specific, new solution (given the market does not offer such a device) situation becomes complicated and a compromise shall be found.

Modular Solutions.

Integration task analysis often makes it unclear why most manufacturers tend to provide complex devices while in many cases much simpler hardware is actually in need. The answer is rather simple: mass production requires universal products to achieve large sale volumes. Most of the aspects of this idea are covered above.

From the other side, even smallest change in the device functionality often demands serious engineering efforts, including development of the new technical solutions, changes in the PCB and casing design, modifications int the manufacturing process and so on; and it's cost is close to the new device development. Larger systems, like notebooks, desktops and mainframes, normally implement the modular design where additional components such as video devices, mass storage, RAM and various I/O hardware could be added easily to the some basic design (fro example, the motherboard). For many reasons this approach is not widely used in the mobile devices domain. Still, we suppose that modular design is available for such class if systems and shows a great potential.



Picture 3

The basic advantages of the modular design are:

- Effectiveness: only necessary to the device's purpose units are used; the customer pays only for what is ordered.
- Predictable result: the units are well tested and ready to use that greatly reduces development risks.
- Development simplicity: the development reduces to the composition of the units, effectively removing the unit's development cost.
- Flexibility: the functionality could be changed later relatively easy.

Unfortunately that approach could not be entirely realized, but the Tancher company proposes the technology that is very close to it.

Tancher's modular design approach

Tancher has the significant experience in the mobile devices development which allows to develop its own approach in creating new mobile solutions.

Hardware

Let's introduce definitions for the module and the platform.

The platform: the set of hardware components that provide basic device functionality (CPU, specific RAM size, power source, auxiliary devices, firmware).

The module: specific peripherals and its software drivers fro different platforms, providing the special functionality.

It is possible to use modular design if there is a standard way to connect any module to the any platform and the software, both drivers and applications, works under every platform.

In this case the customer only has to select the desired platform, set of modules and the device appearance. The rest is to redesign PCB as needed to fit the customer's form-factor greatly reducing the development time and expenses.

The Tancher company has conducted the modern market analysis and proposes three platforms:

Tancher BIRCH platform is intended for the low price niche. It is based on the simple CPU and has limited resources. That platform was used for the CYBIKO XTREME, that worked with CyOS operating system. There is a port of OST (Operating System by Tancher) for it and the wide set of modules and application software.

CYBIKO XTREME mobile wireless computer for teens (Y2001) – (Pic.4)

Features:

- Integrated proprietary wireless link, mesh networks with other devices and wireless gates to the internet
- RF band: 902-928MHz, FSK modulation, 60 channels
- Effective range: 250 meters outdoor
- RF transceiver: RFMD 2915
- CPU: Hitachi HD64F2323, 18МГц
- RAM: FPM DRAM 2Mb
- Storage: FLASH RAM 512Kb
- Display: LCD FSTN 160*100, grayscale, 4 grades.
- Keyboard: QWERTY + gamepad
- Extensions: proprietary cartridge, MP3 player cartridge exists
- External interface: USB 1.0
- Audio: integrated speaker microphone.
- Battery: NiMH
- Dimensions: 81x141x18mm
- Weight: 150g

PICTURE 4

Tancher MAPL platform: is intended to the medium price niche devices. I uses ARM7 CPU and has significantly larger functionality. It works with OST operating system. The platform was used in the specialized GSM/GPRS communicator projects for the Planet Halo (USA) и AT&T Wireless Systems (USA). The platform supports a wide range of modules, what is clearly seen comparing two above mentioned projects.

Planet Halo project (Pic.5)
-Dual-band GSM/GPRS communicator
-QWERTY keyboard
- CyNIX operating system
-160x100 FSTN LCD (grayscale)
-EL keyboard highlight
-ARM7TDMI CPU Samsung S3C44B0X
- SDRAM 16Mb
-FLASH RAM 16Mb
- Navigation wheel
-550 mAh Internal Li-Pol battery
-USB 1.0
-3.5mm audio garniture jack
- 106x82x19mm
- Streamlined case

PICTURE 5

ENIGMA project (Pic.6)
- GSM/GPRS communicator
- 3-band 900/1800/1900MHz GSM/GPRS
- Class 2 Bluetooth
- Integrated antenna
- 240x160 color CSTN display with Front-Light highlighting
- ARM7TDMI Samsung CPU S3C44B0X
- 16Mb SDRAM
- 32Mb FLASH
- 800mAh Li-Ion battery
- 2.5mm audio garniture jack
- QWERTY keyboard with LED highlighting
- Clamshell design for teens
- ICQ and Yahoo Instant Messenger and other chat systems over GPRS
- OST operating system
- Proprietary GUI

- Polyphonic rings
- 97x83x27mm

PICTURE 6

Tancher OAK platform is the enterprise platform. It uses the XScale CPU and has the leading edge functionality. Works with both Windows CE 5.0 and OST. The platform is intended for Hi-End devices and provides maximum number for modules. It was used to the premium class smartphone design for the Mago Mobile company.

Premium Smart Phone (Pic.7)
- GSM/GPRS Smartphone
- 4-band 850/900/1800/1900MHz
- Class 2 Bluetooth
- Wi-Fi 802.11b
- Embedded antenna
- Windows Mobile 2005
- 240x320 2.8” LTPS transflective TFT LCD
- Touch screen
- Intel XScale PXA270 624MHz CPU
- 128Mb SDRAM
- 128Mb Intel Strata Flash
- 1950mAh Li-Ion battery
- 2.5mm stereo audio garniture jack
- USB 2.0 Full Speed
- SD/MMC card slot
- 44 kHz 16 bit Audio Codec (AC97)
- LED keyboard highlighting
- Vibrating alert
- Fully RoHS compliant
- 134x55x15mm

PICTURE 7

The software

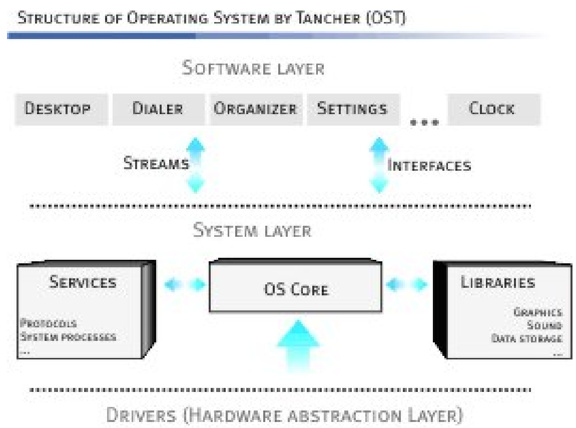
The modular approach in the software is the usual practice widely used almost from the very beginning of the computer programming. In both Windows CE and OST (Operating System by Tancher) this approach was used to full extent providing glut great flexibility and porting ease.

Windows CE 5.0

The system contains isolated core part, BSP (Board Support Package) and device drivers. The core itself is the set of easily configurable parts including end user applications, graphics, multimedia technologies and so on. This way the necessary firmware set could be easily constructed using special platform builder software.

The variety of the resulting builds is impressive: from Tiny Kernel suitable to the controller devices to the Enterprise Terminal and Mobile Handheld.

OST operating system implements the like design and has the following architecture:



Picture8

HAL is the only part of the system that interacts to the hardware. The core uses HAL to provide basic functionality of the protocols and utilities using limited software interfaces. Core implements such basic functionality as protocol stacks, power control including standby-wakeup transitions, timers, streams, pipes, and additional libraries like UI, compression, codecs, multimedia and so on.

OS functions are available with well documented and intuitive C++ interface.

It is possible to develop additional interpreted language modules to run, fro example, Java or Python applications and scripts.

The component structure of the OST allows great scalability and flexibility optimizing system resource consumption to cover the widest range of application.

At the moment the following OST modules are available:

Drivers

- Serial (UART)
- LCD
- Audio over PWM
- Audio AC97
- Highlighting/indication with PWM (brightness control and transitions)
- Keyboard
- NAND-FLASH mass storage
- Filesystem
- Real Time Clock
- Battery driver (charger)
- ADC
- GSM/GPRS module driver
- Bluetooth module driver
- USB Client
- Touch Screen

Protocols

- PPP
- TCP/IP
- BCSP
- HTTP, HTTPS
- SMTP
- POP3
- SSL
- Wireless village

Libraries

- Data compression (bzip and others)
- 2D Graphics including various fonts and image formats, including animated gif, png and jpeg.
- GUI
- AMR, AMR2 codec
- Phone services (calls, SMS, MMS, SIM services, etc.)

Applications

- Desktop
- Voice Dialer
- E-mail with SMS
- Multiprotocol Instant Messenger
- Organizer
- Address Book integrated with other application, such as phone or email.
- Settings
- Web-browser with popular xHtml and CSS subset

Other application and services could be developed easily.
It should be specially noted that OST is initially designed as operating system for the mobile devices using specific design concepts and resource saving technologies, that somewhat complicates software design providing better performance and application flexibility. As the result, OST provides best characteristics with limited resources, for example, improving battery life and reducing necessary memory footprint and CPU power consumption.

Examples from Tancher's practice:

Let's see how the above mentioned design approach could be used in the real world. It is hard to make common quantitative assessments as specific case would vary, so we will use several projects conducted by Tancher Company as the examples if the flexibility and effectiveness of Tancher's modular approach.

1) Labware controller

Goal: labware device to provide flexible automation of the many commonly used measurement and control tasks in scientific setups.

Main requirement: low price, short time.

Batch size: less than 100 units.

In this case there was no processing speed requirement, except for the counter input capable of ~100 MHz counting. PC connection was implemented using UART with special error-safe transport control protocol. Proposed quantities: below one hundred.

Such devices available on the marker cost above $700. Existing devices that could be adapted to suit all requirements cost above $100 and would require extension board development and additional software. Total expenses are close to the new specific device development that is about $5000 for the case.

The solution was made using BIRCH platform with additional counters module implemented on the PLC.

As the result, the development costs was about $2000 and unit price under $100 for the small (less than 100) batch.

2) Shopping mall navigator.

Task: consumer terminal device for the shopping mall (hypermarket) with wireless access to the network resources, positioning service (0.5 meter accuracy), interactive user interface and multimedia capabilities.

Batch size: 10-50k.

The customer considered the usage of the existing PDA with additional RFID cartridge and software. It gives about $200 for PDA and $50 at least for the scanner. It also needs special software development. Using PDA greatly increases the risk of stealing as it is an universal device and could be used outside shopping mall infrastructure as well.

The new device development should cost about $500 000 dollars not including manufacturing set up.

Using MAPL platform it gives development price, taking into consideration the specific design requirements, about $150 000, and BOM unit price is $150 with >10 000 units batch.

Conclusion.

The constantly changing world bears new technologies every few months, which, in turn, rises new tasks and increases hardware manufacturers competition. Existing mobile devices usually does not allow any significant modernization. As the result, there is most often no effectively suitable devices on the market to fit many real automation tasks. Usual (non-modular) approach does not provide sufficient cost effectiveness. Modular design greatly reduces development costs and time, unit price and risks. Using this approach development of the specific devices it is often most effective solution. The advantage of the modular design is most essential with medium and small production batches and pronounced device specific such as limited and soecial functionality, especially when the unit and development price is critical. Following are the examples of the domains where such requirements are likely to appear:

- Retail sales: sales automation, e-kiosk, trader terminal, logistics automation hardware and terminals, quality control automation.
- Manufacturing: control and management terminals, special hardware control systems and like.
- Medical hardware. Personnel terminals allowing access to the hospital (ambulance, polyclinic) databases and various existing measurement, control and other devices.
- Law enforcement and security systems
- Warehouse, storage facilities automation
- Payment systems
- Communications

The Tancher Company supposes that popular ‘all on the chip’ approach won’t be able to beat modular approach in the specific devices market. It is possible that modular approach will become actual standard in the mobile electronics and integration solutions.