TÉCNICO LISBOA

Hardware-Secured System for Secure Communications and Message Exchang

This is the Thesis Subtitle if Necessary

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Information Systems and Computer Engineering

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Acknowledgments

I would like to thank my parents for their friendship, encouragement and caring over all these years, for always being there for me through thick and thin and without whom this project would not be possible. I would also like to thank my grandparents, aunts, uncles and cousins for their understanding and support throughout all these years.

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I would also like to acknowledge my dissertation supervisors Prof. Some Name and Prof. Some Other Name for their insight, support and sharing of knowledge that has made this Thesis possible.

Last but not least, to all my friends and colleagues that helped me grow as a person and were always there for me during the good and bad times in my life. Thank you.

To each and every one of you – Thank you.

Abstract

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Keywords

Maecenas tempus dictum libero; Donec non tortor in arcu mollis feugiat;Cras rutrum pulvinar tellus.

Resumo

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Palavras Chave

Colaborativo; Codificaçãoo; Conteúdo Multimédia; Comunicação;

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1

Introduction

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1.1 Context

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1.4 Services

Certain services are indispensable for the security of the operations. The physical device will provide these services to it's user.

- Secure Storage is critical to save the user's sensitive cryptographic keys and passwords. These objects will be used by the device to secure communications;
- Key management, along with secure storage will allow the generation, revocation and importation of keys when the users deem necessary;
- Confidentiality to keep the contents of the communications secret, except from authorized entities;
- Integrity to safeguard communications from unauthorized modifications;
- Authentication to ascertain the identity of the message sender;
- Non-repudiation to prevent an entity from denying authorship of a message.

Figure 3.2 depicts the client application, interacting with the secure device through the application programming interface (API), the implementation of operations inside the device and secure storage where all the keys are stored.

1.5 Requirements

To offer the aforementioned services the system must comply with multiple requirements:

- The physical box must be tamper-resistant and secure to avoid any damaging attacks;
- The box must be personal, it stores all the user's secrets, such as keys and passwords;
- All critical operations must be performed inside the device and the user's secrets must never be exposed outside the device;
- The system must provide a mechanism of authenticating the user before becoming ready to perform the main operations. The system does not authenticate itself to the user;

- The system must be easy to use to the regular user non-savvy user. It should have a simple interface for the user to execute operations.
- The system should perform the operations in a reasonable time to minimize the user's wait;
- It should be relatively low cost.

2

This is the Second Chapter

Contents

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2.1 Traditional Streaming Technologies

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Sed pulvinar, “felis id consectetuer” malesuada, enim nisl mattis elit, a facilisis tortor nibh quis leo Table 2.1.

Table 2.1: Streaming Technologies Comparison

	Dynamic Streaming	Smooth Streaming	HLS
Streaming Protocol	RTMP	HTTP	HTTP
Video Codec	H.264, VP6	H.264	H.264
Audio Codec	AAC, MP3	WMA, AAC	AAC, MP3
Container Format	MP4, FLV,	MP4	MPEG2-TS
iOS	NO	YES	YES
Android	NO	YES	YES

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Table 2.2: A nice Spreadsheet using package “spreadtab”. Notice the calculations.

22	54	76
43	65	108
49	37	86
114	156	270

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Table 2.3: Comparison between today's and target Architectures of Telcos

Today		Target	
Rigid	Each evolutionary requirement involves development of multiple components, interfaces, platforms,etc.	Flexible	It is possible to modify or add new functionalities rapidly.
Slow	Development of a new application takes months or years.	Fast	Development of a new application takes weeks instead of months or years.
Closed	Limited integration with external environments.	Open	It is simple to integrate internal, applications with external entities.
Complex	Heterogeneous technologies, obsolescence, lack,of standards, high redundancy.	Standardised	Use of homogeneous architectural models.
Expensive	High Capex (for new service development) and,high,Opex (to ensure running of IT).	Cost-Effective	Capex and Opex are optimised.

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3

Solution Architecture

Contents

The objective of the system was to develop a device in a box format to enable users to establish safe channels of communication. This is achieved with a safe and secure device which is personal to each individual. In order to secure the communications between users, the device saves the user's sensitive data, such as keys, and performs all security critical operations. The system is designed so that each user has it's own physical box.

3.1 Components

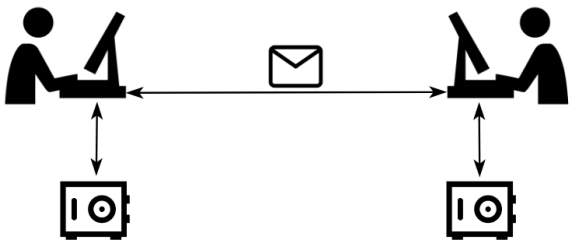

Figure 3.1: Client and device

The solution is composed of two main components, as shown in figure 3.1:

- The physical box which responsible for securing communications;
- The client application on the user's computer which provides an interface for the user to execute operations on the box.

By separating these components, the security of the system is isolated and solely of total responsibility of the box. It is not dependent on the user's personal computer.

Both components are connected through a common interface, such as USB, in order to be more easily accessible to the end users.

Figure 3.2 depicts the client application, interacting with the secure device through the application programming interface (API), the implementation of operations inside the device and secure storage where all the keys are stored.

3.2 Operations

The system operations will ensure the system requirements and services are fulfilled. For the user to be able to execute them, he first must authenticate himself to the device. This is done with a PIN or password, which identifies the user. Once authenticated, the operations will be available to the user to be executed in the box.

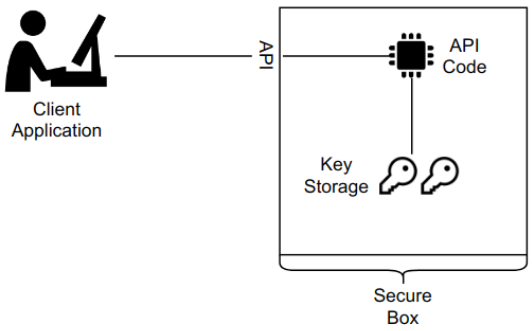

Figure 3.2: Client application and secure device

The operations are split in three types:

- The administration operations manage the authentication and communication configuration;
- The message exchange operations secure the user's communication;
- The key exchange operations manage the keys stored inside the device, which will be used to secure communications.

3.2.1 Administration Operations

The administration operations will allow the user to manage the authentication related parameters. The only operations of this type is to change the authentication PIN. The device will be initialized from fabric with a default PIN which must be supplied to the user. Before performing any operation the user should change his PIN to begin secure communications.

3.2.2 Message Exchange Operations

The main operations will be responsible to secure the communications between users. These operations will fulfill the confidentiality, authentication and non-repudiation services.

- Secure message exchange with confidentiality and authentication. The objective of this operation is to send and receive messages to and from the device. Plaintext messages will be returned to the user encrypted and authenticated with their key stored inside the device. In the case of encrypted and authenticated messages, an error will be returned if the decryption was unsuccessful, otherwise, the user will receive the plaintext message;
- Digital Signature operation will provide non-repudiation to a message. The user will send a message to the box, and the subsequent signature will be returned, which can be used to verify the

message authorship. To verify a signature, the user sends it to the device, and receive the appropriate message, success or failure to verify.

3.2.3 Key Exchange Operations

These operations will handle key exchange when new keys need to be generated and exchanged between users, to enable further communications, and to import other user's public keys. This will serve the secure storage and key management services.

The first operations will enable the user to ask for a new key, generated inside the box, in order to securely send it to another user. The user receiving the new key, generated by another user, will receive and store the key inside the box. The final operation will provide a way to import other user's public keys, as well as export their personal public key, to be shared with another user.

3.3 The Solution in depth

Symmetric keys will be used to encrypt and authenticate messages. They have better performance with larger messages compared to asymmetric keys. Each user can have stored in their box, several symmetric keys. This enables the user to establish secure communications with multiple different people or groups. The non-repudiation property of asymmetric keys will be used to create digital signatures of documents. The other use, will be to share symmetric keys between user who wish to communicate. The box stores the private and public key pair of the user, and the public keys of people the user wishes to trade secrets with.

3.4 Initial State

The users will receive the device with a pair of private and public keys, generated inside the device from fabric. Each device will have the user's public keys, whom he wishes to communicate. The user can request whose public keys he wants, before the device is initialized in fabric. This allows the users to trade symmetric keys between them, which they can user to begin trading messages securely. In addition, the device can also come with a symmetric key stored in each the user's device.

When a new user wants to establish secure communications with an existing user or a group, he must share his public key with the user, ideally physically to ensure there are no mistakes or attacks. After this they can securely share symmetric keys to enable efficient and secure messaging.

3.5 Protocol

A protocol was devised for every operations with different phases and data for each operation.

3.5.1 Authentication Protocol

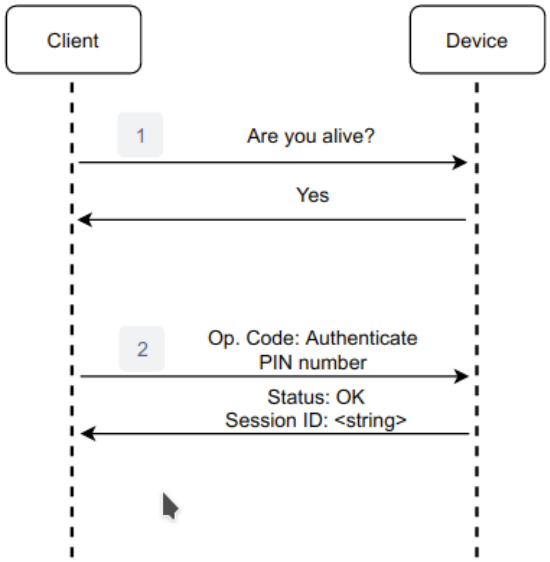

Figure 3.3: Authentication Protocol

Before executing any operation the user must authenticate himself to the device.

1. The first phase is initiated by the user by sending a message to check if the box is alive and connected to the computer.

2. The operation will move to the second phase when the user receives an affirmative response. He will then send the operation code, which indicates he wants to authenticate himself, and the authentication PIN. The device will respond with a status parameter indicating failure or success. When successful the box will also return a session ID string, which the user will need for further operations, to prove he has authenticated himself.

3.5.2 Administration Protocol

As explained before, there is only one administration operation, changing the authentication PIN, pictured in figure 3.4.

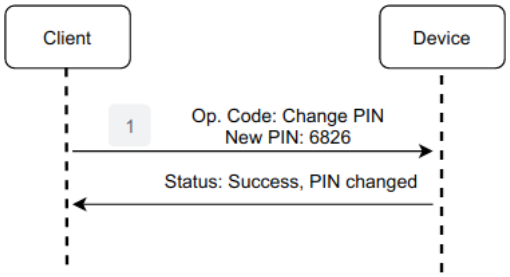

Figure 3.4: Change Authentication PIN protocol

The user initiates by sending the operation code, identifying the operation, the new PIN number and the session ID acquired previously. The device verifies the session ID and send a response, indicating the success or failure of the operation.

3.5.3 Message Exchange Protocol

Protocol to encrypt and authenticate messages:

1. The user sends the operation code, signaling he wants to send a message, and the message size;
2. The box will respond with an OK message that the user can begin transmitting the message. The message will be transmitted a maximum of X bytes per ”packet”. Each packet contains the message information and the size of the message information for that packet. When the transmission ends, the device will confirm the reception;
3. The user subsequently will respond with the symmetric key ID, which he wants to encrypt and authenticate the message with. The box will handle the cryptographic operations and return a status message and the encrypted message size.
4. After the client confirms, the encrypted message with the additional MAC and IV parameters appended, will be returned in the same manner it was sent.

Protocol to decrypt and verify message authentication:

1. The operation code is sent, as well as the encrypted message size;
2. The box will respond with an OK message that the user can begin transmitting the message, one packet at a time;
3. When the message transmission ends, the device will confirm its reception, and the user will subsequently respond with the symmetric key ID, which can decrypt and verify the message authentication;

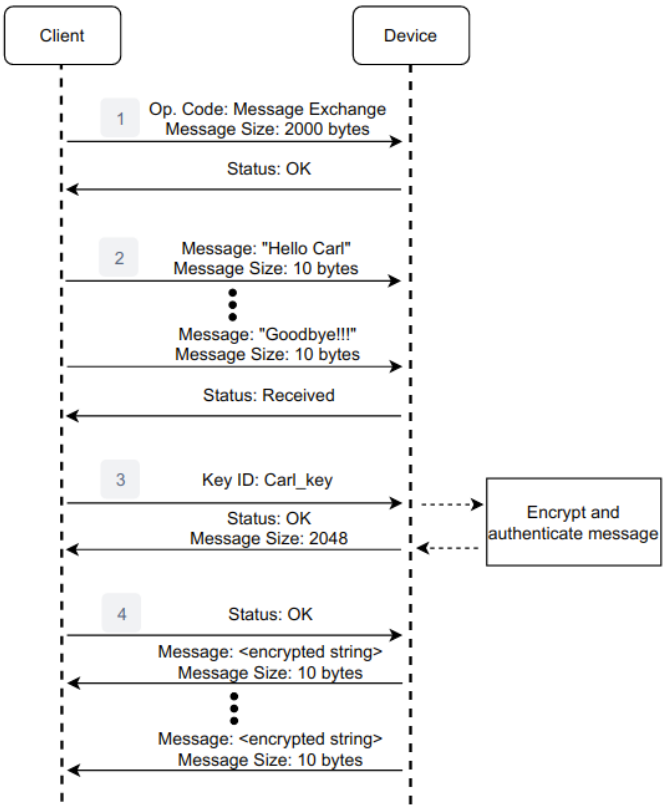

Figure 3.5: Message Exchange Protocol

4. After performing the decryption and authentication operations, the device will return a message indicating its success or failure. In case of a successful operations, it will return, in the same manner it was sent, the plaintext message.

In the case of digital signatures, the user's must have each others public keys, if they do not already have them. Protocol for generating a digital signature:

1. The user initiates with the code operation and the plaintext message size;
2. When the box responds with an OK message, the user transmits the message one packet at a time;
3. In possession of the message, the device will generate the digital signature using the user's private key. When finished the signature is sent back.

Protocol for verifying digital signatures:

1. The user initiates with the code operation;

2. When the box responds with an OK message, the user transmits the message one packet at a time;
3. When done, the user also sends the signature and the name of the signer, so the device knows what public key to use to verify the signature;
4. Then, the device will verify the digital signature using the signer's public key, message and signature. The result will be sent back to the user.

3.5.4 Key Exchange Protocol

Protocol to import public keys:

1. The user send a message with the operation code, indicating he wants to send someone's public key;
2. After the device responds with an OK signal, the user sends the public key, and the name of the owner of the public key;
3. The device then informs the user of the operation's success or failure.

Just like digital signatures, for users to be able to share symmetric keys between each other, they must possess each others public keys in their device. If not, they must physically meet to share them, and import them to their respective devices, with the available operation.

Protocol to send new symmetric key:

1. The user sends a message with the operation code;
2. After the device responds with an OK signal, the user sends the key ID, the name the key will be saved as, and the name of the user he wants to share the key with, so the device knows which public key to use to secure the key;
3. A new symmetric key will be generated and saved in the device's secure storage, with the key ID sent by the user. The box will encrypt and sign the key with public-key cryptography, and send it to the user, which he can securely share with the other user.

Protocol to save new symmetric key, received from another user:

1. The user sends a message with the operation code;
2. After the device responds with an OK signal, the user sends the key ID, the name of the key sender, and the encrypted and signed key;
3. The device will then verify the signature with the sender's public key and decrypt the key, subsequently saving it in the device's secure storage along with other keys already present.

4

This is the Fourth Chapter

Contents

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4.1 Development Process

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- Technology Research and Related Works
- Requirements Gathering and Study
- Design of the Architecture
- Implementation Process
- Testing and Functional Validation

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4.2 Development Environment

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Algorithm 4.1: Time Control Strategy

```
begin
    nextBitrate ⟵ nextDownloadLevel
    nextBitrate ⟵ GetNextBitrate()
    cpuLoad ⟵ GetCpuLoad()
    bitrateDelta ⟵ getBitrateDelta(currentBitrate, nextBitrate)
    if bitrateDelta > maxThreshold then
        SetBitrate(nextBitrate)
    if minThreshold < bitrateDelta < maxThreshold and numAttemps < 2 then
        numAttemps ⟵ numAttemps + 1
    else if minThreshold < bitrateDelta < maxThreshold and numAttemps = 2 then
        numAttemps ⟵ 0
    else
        SetBitrate(nextBitrate)
    if 0 < bitrateDelta < minThreshold and numAttemps < 3 then
        numAttemps ⟵ numAttemps + 1
    else if 0 < bitrateDelta < minThreshold and numAttemps = 3 then
        SetBitrate(nextBitrate)
```

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4.3 Client Application

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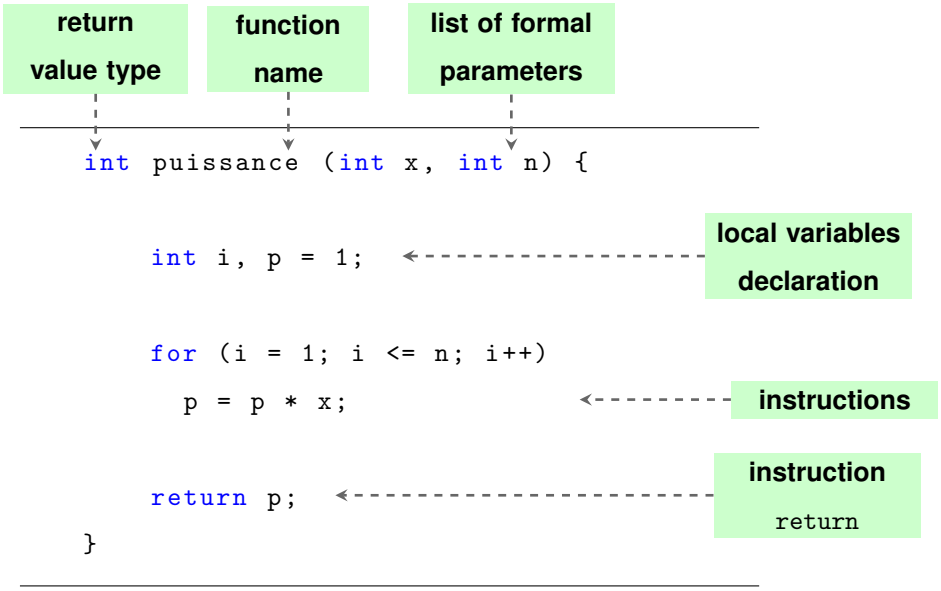

Listagem 4.1: A listing with a Tikz picture overlayed

And here another method (Listing 4.1) for mixing (overlay) a picture with a listing of code.

4.3.1 User Interface

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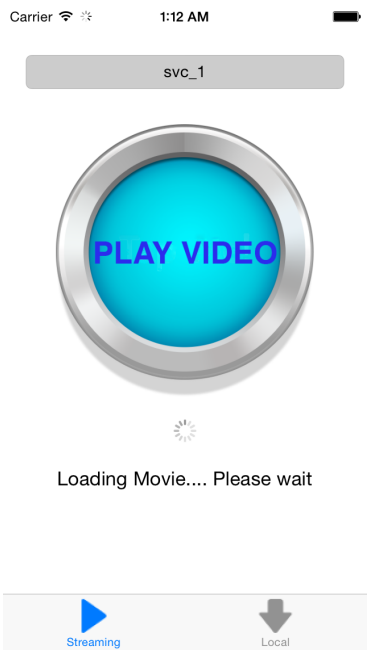
4.3.2 Vivamus luctus elit sit amet mi

Nulla facilisi. In vel sem. Morbi id urna in diam dignissim feugiat. Proin molestie tortor eu velit. Aliquam erat volutpat. Nullam ultrices, diam tempus vulputate egestas, eros pede varius leo, sed imperdiet lectus est ornare odio. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Proin consectetuer velit in dui. Phasellus wisi purus, interdum vitae, rutrum accumsan, viverra in, velit. Sed enim risus, congue non, tristique in, commodo eu, metus. Aenean tortor mi, imperdiet id, gravida eu, posuere eu, felis.

Mauris sollicitudin, turpis in hendrerit sodales, lectus ipsum pellentesque ligula, sit amet scelerisque

urna nibh ut arcu. Aliquam in lacus.

Figures 4.1(a) and 4.1(b) proin at eros non eros adipiscing mollis.



(a) Media Loading Window

(b) Play-out Session UI

Figure 4.1: Complete User Interface

Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Nulla placerat aliquam wisi. Mauris viverra odio. Quisque fermentum pulvinar odio. Proin posuere est vitae ligula. Etiam euismod. Cras a eros.

5

This is the Fifth Chapter

Contents

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim. Suspendisse id velit vitae ligula volutpat condimentum. Aliquam erat volutpat. Sed quis velit. Nulla facilisi. Nulla libero. Vivamus pharetra posuere sapien. Nam consectetuer. Sed aliquam, nunc eget euismod ullamcorper, lectus nunc ullamcorper orci, fermentum bibendum enim nibh eget ipsum. Donec porttitor ligula eu dolor. Maecenas vitae nulla consequat libero cursus venenatis. Nam magna enim, accumsan eu, blandit sed, blandit a, eros.

5.1 Maecenas vitae nulla consequat

Aliquam aliquet, est a ullamcorper condimentum, tellus nulla fringilla elit, a iaculis nulla turpis sed wisi. Fusce volutpat. Etiam sodales ante id nunc. Proin ornare dignissim lacus. Nunc porttitor nunc a sem. Sed sollicitudin velit eu magna. Aliquam erat volutpat. Vivamus ornare est non wisi. Proin vel quam. Vivamus egestas. Nunc tempor diam vehicula mauris. Nullam sapien eros Figure 5.1, facilisis vel, eleifend non, auctor dapibus, pede.

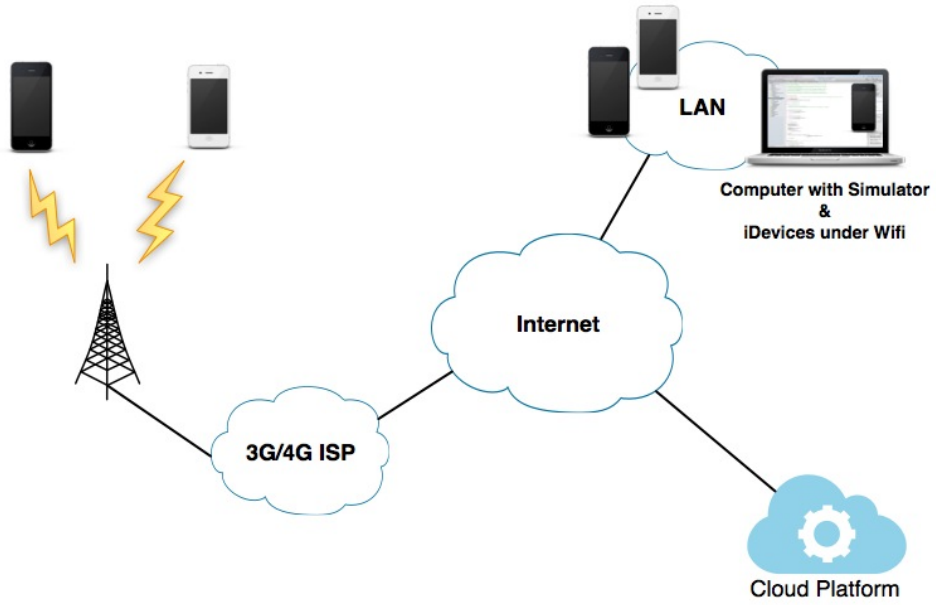


Figure 5.1: Test Environment

Aliquam aliquet, est a ullamcorper condimentum, tellus nulla fringilla elit, a iaculis nulla turpis sed wisi. Fusce volutpat. Etiam sodales ante id nunc. Proin ornare dignissim lacus. Nunc porttitor nunc a sem. Sed sollicitudin velit eu magna. Aliquam erat volutpat. Vivamus egestas. Nunc tempor diam vehicula mauris. Nullam sapien eros, facilisis vel, eleifend non, auctor dapibus, pede Table 5.1 used in the tests. The Network Link Conditioner allows to force/simulate fluctuations in fixed network segments.

Table 5.1: Network Link Conditioner Profiles

Network Profile	Bandwidth	Packets Droped	Delay
Wifi	40 mbps	0%	1 ms
3G	780 kbps	0%	100 ms
Edge	240 kbps	0%	400 ms

Aliquam aliquet, est a ullamcorper condimentum, tellus nulla fringilla elit, a iaculis nulla turpis sed wisi. Fusce volutpat. Etiam sodales ante id nunc. Proin ornare dignissim lacus. Nunc porttitor nunc a sem. Sed sollicitudin velit eu magna. Aliquam erat volutpat. Vivamus ornare est non wisi. Proin vel quam. Vivamus egestas. Nunc tempor diam vehicula mauris. Nullam sapien eros, facilisis vel, eleifend non, auctor dapibus, pede.

5.2 Proin ornare dignissim lacus

Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Vestibulum tortor quam, feugiat vitae, ultricies eget, tempor sit amet, ante. Donec eu libero sit amet quam egestas semper. Aenean ultricies mi vitae est. Mauris placerat eleifend leo. Quisque sit amet est et sapien ullamcorper pharetra. Vestibulum erat wisi, condimentum sed, commodo vitae, ornare sit amet, wisi. Aenean fermentum, elit eget tincidunt condimentum, eros ipsum rutrum orci, sagittis tempus lacus enim ac dui. Donec non enim in turpis pulvinar facilisis. Ut felis.

Et “optimistic” nulla dui purus, eleifend vel, consequat non, dictum porta, nulla. Duis ante mi, laoreet ut, commodo eleifend, cursus nec, lorem. Aenean eu est. Etiam imperdiet turpis. Praesent nec augue. Curabitur ligula quam, rutrum id, tempor sed, consequat ac, dui G_j, nec ligula et lorem consequat ullamcorper p ut mauris eu mi mollis luctus j, porttitor ut, Equation (5.1), uctus posuere justo:

N_j Is the number of times peer j has been optimistically unchoked.

n_j Among the N_j unchokes, the number of times that peer j responded with unchoke or supplied segments to peer p.

$C_{r[j]}$ The cooperation ratio of peer j. If peer j never supplied peer p, the information of $C_{r[j]}$ may not be available.

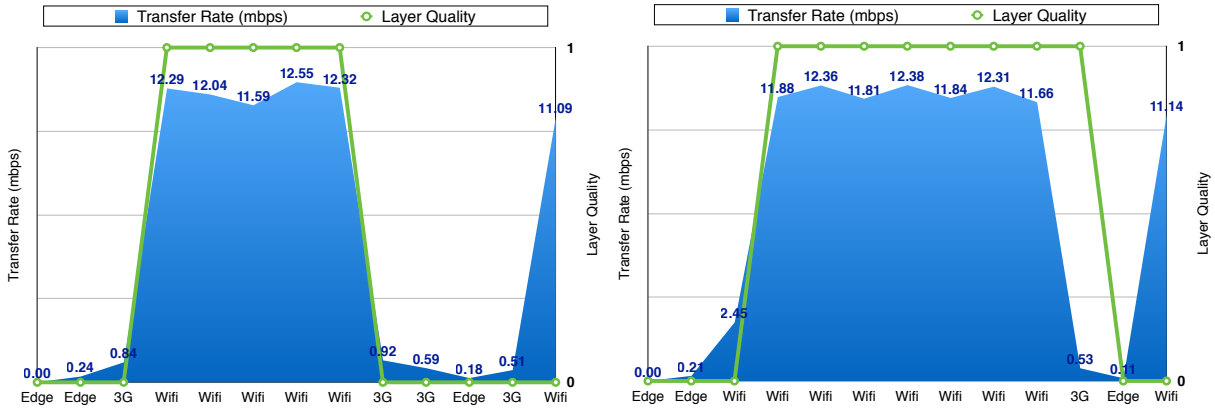
$C_{r(max)}$ The maximum cooperation ratio of peer p's neighbors, i.e., $C_{r(max)} = max(C_r)$.

$$G_j = \begin{cases} \dfrac{n_j C_{r[j]}}{N_j} & \text{if } n_j > 0 \\ \dfrac{C_{r(max)}}{N_j + 1} & \text{if } n_j = 0 \end{cases} \tag{5.1}$$

Cursus $C_{r(max)}$ conubia nostra, per inceptos hymenaeos j gadipiscing mollis massa $N_j = 0$, unc ut dui eget nulla venenatis aliquet $G_j = C_{r(max)}$.

Vestibulum accumsan eros nec magna. Vestibulum vitae dui. Vestibulum nec ligula et lorem consequat ullamcorper. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Phasellus eget nisl ut elit porta ullamcorper. Maecenas tincidunt velit quis orci. Sed in dui. Nullam ut mauris eu mi mollis luctus. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Sed cursus cursus velit. Sed a massa.

Both Figures 5.2(a) and 5.2(b) Phasellus eget nisl ut elit porta “perfect” tincidunt. Class aptent taciti sociosqu ad litora torquent per conubia nostra.



(a) Adaptation System Test 4

(b) Adaptation System Test 5

Figure 5.2: Adaptation System Behavior Test

Cras sed ante. Phasellus in massa. Curabitur dolor eros, gravida et, hendrerit ac, cursus non, massa. Aliquam lorem. In hac habitasse platea dictumst. Cras eu mauris. Quisque lacus. Donec ipsum. Nullam vitae sem at nunc pharetra ultricies. Vivamus elit eros, ullamcorper a, adipiscing sit amet, porttitor ut, nibh. Maecenas adipiscing mollis massa. Nunc ut dui eget nulla venenatis aliquet. Sed luctus posuere justo. Cras vehicula varius turpis. Vivamus eros metus, tristique sit amet, molestie dignissim, malesuada et, urna.

6

Conclusion

Contents

Pellentesque vel dui sed orci faucibus iaculis. Suspendisse dictum magna id purus tincidunt rutrum. Nulla congue. Vivamus sit amet lorem posuere dui vulputate ornare. Phasellus mattis sollicitudin ligula. Duis dignissim felis et urna. Integer adipiscing congue metus.

6.1 Conclusions

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non, tristique in, commodo eu, metus. Aenean tortor mi, imperdiet id, gravida eu, posuere eu, felis. Mauris sollicitudin, turpis in hendrerit sodales, lectus ipsum pellentesque ligula, sit amet scelerisque urna nibh ut arcu. Aliquam in lacus. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Nulla placerat aliquam wisi. Mauris viverra odio. Quisque fermentum pulvinar odio. Proin posuere est vitae ligula. Etiam euismod. Cras a eros.

Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce neque dolor, adipiscing sed, consectetuer et, lacinia sit amet, quam.

6.2 System Limitations and Future Work

Aliquam aliquet, est a ullamcorper condimentum, tellus nulla fringilla elit, a iaculis nulla turpis sed wisi. Fusce volutpat. Etiam sodales ante id nunc. Proin ornare dignissim lacus. Nunc porttitor nunc a sem. Sed sollicitudin velit eu magna. Aliquam erat volutpat. Vivamus ornare est non wisi. Proin vel quam. Vivamus egestas. Nunc tempor diam vehicula mauris. Nullam sapien eros, facilisis vel, eleifend non, auctor dapibus, pede.

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A

Code of Project

Nulla dui purus, eleifend vel, consequat non, dictum porta, nulla. Duis ante mi, laoreet ut, commodo eleifend, cursus nec, lorem. Aenean eu est. Etiam imperdiet turpis. Praesent nec augue. Curabitur ligula quam, rutrum id, tempor sed, consequat ac, dui. Vestibulum accumsan eros nec magna. Vestibulum vitae dui. Vestibulum nec ligula et lorem consequat ullamcorper.

Listagem A.1: Example of a XML file.

```
1 <?xml version="1.0" encoding="UTF-8"?>
2 <StreamInfo version="2.0">
3     <Clip duration="PT01M0.00S">
4         <BaseURL>videos/</BaseURL>
5         <Description>svc_1</Description>
6         <Representation mimeType="video/SVC" codecs="svc" frameRate="30.00" bandwidth="401.90"
7             width="176" height="144" id="L0">
8             <BaseURL>svc_1/</BaseURL>
9             <SegmentInfo from="0" to="11" duration="PT5.00S">
```

```
10              <BaseURL>svc_1-L0-</BaseURL>
11          </SegmentInfo>
12      </Representation>
13      <Representation mimeType="video/SVC" codecs="svc" frameRate="30.00" bandwidth="1322.60"
14          width="352" height="288" id="L1">
15          <BaseURL>svc_1/</BaseURL>
16          <SegmentInfo from="0" to="11" duration="PT5.00S">
17              <BaseURL>svc_1-L1-</BaseURL>
18          </SegmentInfo>
19      </Representation>
20  </Clip>
21 </StreamInfo>
```

Etiam imperdiet turpis. Praesent nec augue. Curabitur ligula quam, rutrum id, tempor sed, consequat ac, dui. Maecenas tincidunt velit quis orci. Sed in dui. Nullam ut mauris eu mi mollis luctus. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Sed cursus cursus velit. Sed a massa. Duis dignissim euismod quam.

Listagem A.2: Assembler Main Code.

```
; ********************************************************************
; * Constantes
; ********************************************************************

ON     EQU 1 ; contagem ligada
OFF    EQU 0 ; contagem desligada
INPUT  EQU 8000H ; endereço do porto de entrada
           ;(bit 0 = RTC; bit 1 = botão)
OUTPUT  EQU 8000H ; endereço do porto de saída.


; ********************************************************************
; * Stack
; ********************************************************************

PLACE   1000H
pilha:    TABLE 100H  ; espaço reservado para a pilha
fim_pilha:

; ********************************************************************

PLACE   2000H

; Tabela de vectores de interrupção

tab:    WORD  rot0

; ********************************************************************
; * Programa Principal
; ********************************************************************

PLACE   0

inicio:
  MOV BTE, tab     ; incializa BTE
  MOV R9, INPUT    ; endereço do porto de entrada
  MOV R10, OUTPUT    ; endereço do porto de Ìsada
  MOV SP, fim_pilha
  MOV R5, 1      ; inicializa estado do processo P1
  MOV R6, 1      ; inicializa estado do processo P2
  MOV R4, OFF      ; inicializa controle de RTC
  MOV R8, 0      ; inicializa contador
  MOV R7, OFF      ; inicialmente não permite contagem
  EI0           ; permite interrupções tipo 0
```

```
45    EI            ; activa interrupções
46
47  ciclo:
48    CALL  P1      ; invoca processo P1
49    CALL  P2      ; invoca processo P2
50    JMP   ciclo   ; repete ciclo
51
52  ; ********************************************************************
53  ;* ROTINAS
54  ; ********************************************************************
55
56  P1:
57    CMP R5, 1     ; se estado = 1
58    JZ  P1_1
59    CMP R5, 2     ; se estado = 2
60    JZ  P1_2
61  sai_P1:
62    RET         ; sai do processo.
63
64
65  P1_1:
66    MOVB  R0, [R9]  ; lê porto de entrada
67    BIT R0, 1
68    JZ  sai_P1    ; se botão não carregado, sai do processo
69    MOV R7, ON    ; permite contagem do display
70    MOV R5, 2   ; passa ao estado 2 do P1
71    JMP sai_P1
72
73  P1_2:
74    MOVB  R0, [R9]  ; lê porto de entrada
75    BIT R0, 1
76    JNZ sai_P1    ; se botão continua carregado, sai do processo
77    MOV R7, OFF   ; caso contrário, desliga contagem do display
78    MOV R5, 1   ; passa ao estado 1 do P1
79    JMP sai_P1
```

Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Phasellus eget nisl ut elit porta ullamcorper. Maecenas tincidunt velit quis orci. Sed in dui. Nullam ut mauris eu mi mollis luctus. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos.

This inline MATLAB code `for i=1:3, disp('cool'); end;` uses the `\mcode{}` command.[1]

Nullam ut mauris eu mi mollis luctus. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Sed cursus cursus velit. Sed a massa. Duis dignissim euismod quam. Nullam euismod metus ut orci.

Listagem A.3: `Matlab Function`

```
1  for i = 1:3
2      if i >= 5 && a ~= b       % literate programming replacement
3          disp('cool');         % comment with some LaTeXin it:  πx^2
4      end
5      [:,ind] = max(vec);
6      x_last = x(1,end) - 1;
7      v(end);
8      ylabel('Voltage (μV)');
9  end
```

[1] MATLAB Works also in footnotes: `for i=1:3, disp('cool'); end;`

Nullam ut mauris eu mi mollis luctus. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Sed cursus cursus velit. Sed a massa. Duis dignissim euismod quam. Nullam euismod metus ut orci.

Listagem A.4: `function.m`

```
%   Copyright 2010 The MathWorks, Inc.
function ObjTrack(position)
% #codegen
% First, setup the figure
numPts = 300;              % Process and plot 300 samples
figure;hold;grid;          % Prepare plot window
% Main loop
for idx = 1: numPts
    z = position(:,idx);   % Get the input data
    y = kalmanfilter(z);   % Call Kalman filter to estimate the position
    plot_trajectory(z,y);  % Plot the results
end
hold;
end   % of the function
```

Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Phasellus eget nisl ut elit porta ullamcorper. Maecenas tincidunt velit quis orci. Sed in dui. Nullam ut mauris eu mi mollis luctus. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Sed cursus cursus velit. Sed a massa. Duis dignissim euismod quam. Nullam euismod metus ut orci. Vestibulum erat libero, scelerisque et, porttitor et, varius a, leo.

Listagem A.5: HTML with CSS Code

```
<!DOCTYPE html>
<html>
  <head>
    <title>Listings Style Test</title>
    <meta charset="UTF-8">
    <style>
      /* CSS Test */
      * {
        padding: 0;
        border: 0;
```

```
        margin: 0;
      }
    </style>
    <link rel="stylesheet" href="css/style.css" />
  </head>
  <header> hey </header>
  <article> this is a article </article>
  <body>
    <!-- Paragraphs are fine -->
    <div id="box">
      <p>
        Hello World
      </p>
      <p>Hello World</p>
      <p id="test">Hello World</p>
      <p></p>
    </div>
    <div>Test</div>
    <!-- HTML script is not consistent -->
    <script src="js/benchmark.js"></script>
    <script>
      function createSquare(x, y) {
        // This is a comment.
        var square = document.createElement('div');
        square.style.width = square.style.height = '50px';
        square.style.backgroundColor = 'blue';

        /*
         * This is another comment.
         */
        square.style.position = 'absolute';
        square.style.left = x + 'px';
        square.style.top = y + 'px';

        var body = document.getElementsByTagName('body')[0];
        body.appendChild(square);
      };

```

```
49        // Please take a look at +=
50        window.addEventListener('mousedown', function(event) {
51          // German umlaut test: Berührungspunkt ermitteln
52          var x = event.touches[0].pageX;
53          var y = event.touches[0].pageY;
54          var lookAtThis += 1;
55        });
56      </script>
57    </body>
58  </html>
```

Nulla dui purus, eleifend vel, consequat non, dictum porta, nulla. Duis ante mi, laoreet ut, commodo eleifend, cursus nec, lorem. Aenean eu est. Etiam imperdiet turpis. Praesent nec augue. Curabitur ligula quam, rutrum id, tempor sed, consequat ac, dui. Vestibulum accumsan eros nec magna. Vestibulum vitae dui. Vestibulum nec ligula et lorem consequat ullamcorper.

Listagem A.6: HTML CSS Javascript Code

```
1
2  @media only screen and (min-width: 768px) and (max-width: 991px) {
3
4    #main {
5      width: 712px;
6      padding: 100px 28px 120px;
7    }
8
9    /* .mono {
10     font-size: 90%;
11   } */
12
13   .cssbtn a {
14     margin-top: 10px;
15     margin-bottom: 10px;
16     width: 60px;
17     height: 60px;
18     font-size: 28px;
19     line-height: 62px;
20   }
```

Nulla dui purus, eleifend vel, consequat non, dictum porta, nulla. Duis ante mi, laoreet ut, commodo eleifend, cursus nec, lorem. Aenean eu est. Etiam imperdiet turpis. Praesent nec augue. Curabitur ligula quam, rutrum id, tempor sed, consequat ac, dui. Vestibulum accumsan eros nec magna. Vestibulum vitae dui. Vestibulum nec ligula et lorem consequat ullamcorper.

Listagem A.7: PYTHON Code

```
1 class TelgramRequestHandler(object):
2     def handle(self):
3         addr = self.client_address[0]          # Client IP-adress
4         telgram = self.request.recv(1024)      # Recieve telgram
5         print "From: %s, Received: %s" % (addr, telgram)
6         return
```

B

A Large Table

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Table B.1: Example table

Benchmark: ANN	**#Layers** (1)	**#Nets** (2)	#Nodes* (3) = 8 · (1) · (2)	Critical path (4) = 4 · (1)	**Latency (T_{iter})** (5)
A1	**3–1501**	1	**24–12008**	**12–6004**	4
A2	501	1	4008	2004	**2–2000**
A3	10	**2–1024**	**160–81920**	40	60†
A4	10	50	4000	40	**80–1200**

Benchmark: FFT	**FFT size‡** (1)	*#Inputs* (2) = $2^{(1)}$	*#Nodes** (3) = 10 · (1) · (2)	*Critical path* (4) = 4 · (1)	**Latency (T_{iter})** (5)
F1	**1–10**	2–1024	**20–102400**	4–40	6–60†
F2	**5**	32	1600	20	**40 – 1500**

Benchmark: Random networks	**#Types** (1)	**#Nodes** (2)	*#Networks* (3)	*Critical path* (4)	**Latency (T_{iter})** (5)
R1	3	10–2000	500	*variable*	(4)
R2	3	50	500	*variable*	(4) × [1; · · · ; 20]

* *Excluding constant nodes.*
† *Value kept proportional to the critical path:* $(5) = (4) * 1.5$.
‡ *A size of x corresponds to a 2^x point FFT.*
Values in bold indicate the parameter being varied.

As Table B.1 shows, the data can be inserted from a file, in the case of a somehow complex structure. Notice the Table footnotes.

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And now an example (Table B.2) of a table that extends to more than one page. Notice the repetition of the Caption (with indication that is continued) and of the Header, as well as the continuation text at the bottom.

Table B.2: Example of a very long table spreading in several pages

Time (s)	Triple chosen	Other feasible triples
0	(1, 11, 13725)	(1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0)
2745	(1, 12, 10980)	(1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0)
5490	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
8235	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
10980	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)

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Table B.2 – continued from previous page

Time (s)	Triple chosen	Other feasible triples
13725	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
16470	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
19215	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
21960	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
24705	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
27450	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
30195	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
32940	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
35685	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
38430	(1, 13, 10980)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
41175	(1, 12, 13725)	(1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
43920	(1, 13, 10980)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
46665	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
49410	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
52155	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
54900	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
57645	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
60390	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
63135	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
65880	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
68625	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
71370	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
74115	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
76860	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
79605	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
82350	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
85095	(1, 12, 13725)	(1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
87840	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
90585	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
93330	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
96075	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
98820	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
101565	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
104310	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
107055	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
109800	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
112545	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
115290	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
118035	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
120780	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
123525	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
126270	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
129015	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
131760	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
134505	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
137250	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
139995	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
142740	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
145485	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
148230	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)

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Time (s)	Triple chosen	Other feasible triples
150975	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
153720	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
156465	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
159210	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
161955	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
164700	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)