



**JOÃO RICARDO BOGALHO BRILHA**  
BSc in Computer Science and Engineering

## MICROBABEL

A MULTI-PROTOCOL APPROACH FOR RESILIENT  
AND DECENTRALIZED IOT NETWORKS

MASTER IN COMPUTER SCIENCE AND ENGINEERING  
SPECIALIZATION IN DISTRIBUTED AND PARALLEL SYSTEMS

NOVA University Lisbon

*Draft: January 4, 2026*



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## ABSTRACT

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2. Why is this problem interesting/challenging?
3. What is the proposed approach/solution/contribution?
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**Keywords:** One keyword · Another keyword · Yet another keyword · One keyword more · The last keyword

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1. Qual é o problema?
2. Porque é que é um problema interessante/desafiante?
3. Qual é a proposta de abordagem/solução?
4. Quais são as consequências/resultados da solução proposta?

**Palavras-chave:** Primeira palavra-chave · Outra palavra-chave · Mais uma palavra-chave · A última palavra-chave

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## GLOSSARY

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## INTRODUCTION

The proliferation of Internet of Things (IoT) devices has changed how we monitor and interact with physical spaces – from smart homes to industrial facilities – with the global IoT market reaching 18.5 billion connected devices in 2024, and projected to reach 39 billion by 2030[21], with industry analysts estimating that IoT technologies could unlock between \$5.5 and \$12.6 trillion in economic value by the same year[5].

However, current IoT systems remain fundamentally dependent on continuous Internet connectivity and centralized cloud infrastructures[28, 8]. The dominant architectural pattern across the industry involves edge devices collecting data and transmitting it to remote cloud servers for processing, storage, and other control logic. This approach delivers scalability and ease of management but creates a fundamental dependency on network availability.

This centralized model introduces several concerns beyond just connectivity: operational costs for cloud services create economic dependencies on third-party providers and often lead to vendor lock-in, data sovereignty issues arise when sensitive information must travel to and reside on external infrastructure, and system resilience becomes fundamentally tied to the availability of these remote services.

While cloud platforms can benefit IoT deployments through additional computational resources and storage capacity, systems that *depend* on constant cloud connectivity sacrifice local autonomy and introduce single points of failure. This cloud-centric model has enabled rapid IoT adoption, but introduces critical vulnerabilities across scenarios where continuous connectivity cannot be guaranteed.

Recent infrastructure failures illustrate the fragility of cloud-dependent architectures: the AWS US-EAST-1 outage in October 2025[23] disrupted services from banking to smart homes worldwide, demonstrating how a DNS configuration error in a *single region* can cascade into global disruptions[22].

Attempts have been made to address these challenges through incremental improvements, such as shifting focus to edge computing in order to reduce latency[8, 28, 19], redundant cloud regions for availability[15, 14], and hybrid architectures that combine local and remote processing[1, 6, 10].

However, these solutions remain fundamentally tied to the assumption of eventual connectivity, and often increase system complexity without eliminating the core dependency. This leads to shortcomings in key areas that demand more fundamental architectural reconsideration:

#### Limited suitability for hazardous environments

Remote or dangerous locations (industrial sites, disaster-prone areas) require systems that can operate reliably without constant human intervention or stable network infrastructure;

#### Lack of autonomous operation

Device deployment and operation en masse can be brittle, with little tolerance for individual node failures in the IoT infrastructure, which is naturally susceptible to network failures and intermittent connectivity;

#### Privacy and data sovereignty concerns

Cloud platforms and other third-parties are oftentimes an unavoidable middle layer between end devices and end users, raising questions about data processing and control.

While these challenges affect both IoT and domotics systems alike – from industrial monitoring to residential automation – they become particularly acute in disaster response and emergency scenarios, where communication infrastructure fails precisely when needed most, rapid deployment with minimal configuration becomes essential, and autonomous operation transitions from desirable to indispensable.

During earthquakes, floods, and other emergencies, the need for real-time sensor data (structural integrity, air quality, evacuation routes) and bidirectional communication (threat alerts, user feedback) becomes critical, yet traditional infrastructure often fails first, eliminating both cloud connectivity and local network access points that deployed devices rely on.

A pragmatic issue in the context of smart homes is that without cloud connectivity, users cannot interact with their appliances, such that during a Wi-Fi outage smart lights become uncontrollable despite all hardware being physically present. While merely inconvenient domestically, this architectural dependency has critical implications in other contexts and **MicroBabel** addresses such scenarios across scales: from residential systems requiring local control, to building monitoring infrastructures that must operate during emergencies, to disaster response networks where autonomous operation becomes essential when traditional infrastructure fails.

While cloud platforms like Amazon Alexa, Google Home, and Microsoft Azure IoT Hub offer convenience for data processing and remote device control, their inherent dependence on continuous Internet connectivity introduces some critical limitations: increased latency from round-trip communication to distant servers[19, 17], reduced

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availability during network disruptions or cloud outages[27, 14], and poor fault-tolerance when infrastructure fails[2].

These characteristics make cloud-centric architectures fundamentally unsuitable for scenarios that require or prioritize local operation, autonomous behavior, or guaranteed responsiveness during emergencies.

The Babel Ecosystem [7] addresses these limitations by enabling devices to operate autonomously without cloud infrastructure, while still supporting cloud integration when connectivity is available and desired.

In this document we introduce **MicroBabel**, a lightweight framework targeting embedded platforms (ESP32, Raspberry Pi Pico) aimed at developing resilient, multi-protocol and decentralized IoT systems that can operate autonomously during infrastructure failures. **MicroBabel** integrates with the broader Babel Ecosystem, which runs hardware with greater resources such as full Raspberry Pi boards or computers, enabling a tiered architecture where resource-constrained edge devices can seamlessly interoperate with computational nodes for data aggregation, processing, and coordination.

## Research Topics

We focus on three main research questions:

### **How can these systems maintain communication when traditional infrastructure fails?**

Traditional IoT deployments rely heavily on Wi-Fi access points, cellular towers, or other centralized infrastructure that often becomes unavailable during disasters, or is altogether unreliable in remote locations. **MicroBabel** addresses this by leveraging a multi-protocol communication approach, supporting a diverse protocol stack (Bluetooth Low Energy (BLE), LoRa, ESP-NOW, ZigBee, infrared) that can operate independently of infrastructure.

By enabling adaptive protocol selection and peer-to-peer mesh formation, devices can establish alternative communication paths when primary channels fail.

### **How can device heterogeneity be leveraged to create and orchestrate these networks?**

IoT deployments naturally comprise devices with varying capabilities, from resource-constrained sensors, to gateway nodes with greater processing power and storage. Rather than treating this heterogeneity as a limitation, **MicroBabel** exploits it through capability-aware protocols that allow devices to negotiate roles dynamically via discovery.

Resource-rich nodes can serve as data aggregation and processing points, or bridges between a remote deployment and traditional network infrastructure (if desired), while simpler devices focus on sensing and actuation, creating a resilient multi-tier architecture.

### **How can we achieve (near-)zero-configuration deployment for emergency scenarios?**

Emergency response and hazardous environment monitoring demand systems that can be deployed rapidly without extensive configuration. **MicroBabel** provides automatic peer

discovery across multiple protocols, self-organizing network formation, and decentralized coordination mechanisms that eliminate the need for pre-configured master nodes or manual network planning.

Devices autonomously establish connectivity with each other, negotiate protocols, and begin operation upon being activated, enabling deployment by non-technical personnel or in hard-to-reach locations.

## Contributions

We plan to make the following contributions:

- A decentralized architecture supporting multiple communication channels (BLE, LoRa, ZigBee, ESP-NOW, IR) with adaptive protocol switching based on Quality of Service (QoS) requirements, resource availability and device capabilities;
- A resource-efficient programming framework for embedded platforms that enables autonomous operation without central coordination, providing abstractions for multi-protocol communication, peer discovery, and opportunistic data forwarding;
- A proof-of-concept implementation demonstrating infrastructure- independent operation and automatic disaster-mode failover in a real-world deployment.

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## RELATED WORK

Internet of Things (IoT) and home automation (domotics) systems share the same technological building blocks (wireless sensors, embedded devices, network communication) but diverge significantly in their operational focus and architectures:

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**IoT systems** typically focus on **data collection and monitoring**, by streaming sensor readings to centralized platforms for analysis and processing, with control functions often being a secondary concern.

**Domotics systems** instead prioritize **real-time control and actuation** over physical spaces, where responsiveness and local autonomy are paramount for end user experience and privacy.

This distinction gains additional relevance when focusing on resilience requirements: while IoT deployments may tolerate delayed data aggregation and/or temporary connectivity issues in monitoring scenarios, domotics applications (such as emergency lighting control or HVAC management) demand immediate local response regardless of network conditions.

Both domains, however, suffer from a common vulnerability when confronted with infrastructure failures during disasters: their predominantly cloud-centric architectures collapse precisely when autonomous operation becomes indispensable.

The challenges faced by disaster-resilient IoT systems span multiple dimensions:

**Infrastructure failures** eliminate access points that devices depend on for coordination;

**Intermittent connectivity** creates network partitions where subgroups of devices must operate autonomously without global state synchronization;

**Resource constraints** limit the computational, memory and energy budgets available for implementing sophisticated resilience mechanisms in embedded platforms.

**MicroBabel** addresses these concerns through a decentralized approach that aims to eliminate the dependency on centralized coordination, continuous connectivity and cloud infrastructure.

Rather than treating infrastructure failures as an exceptional condition requiring failover mechanisms, our architecture focuses on autonomous peer-to-peer connectivity as the baseline mode of operation, with infrastructure integration as an added benefit when available, rather than a hard dependency.

This approach means rethinking multiple aspects of traditional IoT systems design: from multi-protocol communication strategies that adapt to the available mediums and device resources without centralized control, to gossip-based synchronization mechanisms that achieve coordination through local interactions, to lightweight data compression techniques to make the most out of the limited storage and battery available in each device.

The following sections briefly cover related work across five areas that collectively enable autonomous operation: (Section 2.1) multi-protocol communication and adaptive selection based on QoS and device capabilities; (Section 2.2) peer-to-peer mesh networking and topology management for autonomous network formation without coordinator dependencies; (Section 2.3) decentralized synchronization mechanisms for coordinating multi-protocol communication without master nodes; (Section 2.4) lightweight data compression and energy optimization techniques to extend autonomous operation duration and device lifetime; and (Section 2.5) security and privacy mechanisms that enable systems to maintain secure communication after infrastructure failures.

For each area, we examine how existing approaches handle (or fail to handle) infrastructure failure scenarios, identify architectural assumptions that conflict with disaster-resilient requirements, and position **MicroBabel**'s contributions relative to the current state of the art.

## 2.1 Multi-Protocol Communication and Adaptive Protocol Selection

Single-protocol (i.e. Wi-Fi only, BLE only, LoRa only, etc.) communication architectures are susceptible to a fundamental vulnerability: if their chosen medium becomes unavailable or inefficient due to interference, range limitations, or infrastructure failures, the entire system loses connectivity and most times ceases to function altogether.

This becomes especially grave in disaster scenarios where communication conditions change unpredictably due to factors such as RF interference from debris, obstacles blocking line-of-sight propagation, or damage to access points.

Existing approaches to multi-protocol IoT systems can be placed in three categories: multi-channel resilience architectures that orchestrate communication technologies for emergency scenarios; implementations that show the feasibility of protocol heterogeneity

on embedded platforms; and adaptive selection frameworks that switch protocols based on runtime conditions.

### 2.1.1 Multi-Channel Resilience Architectures

Several disaster-focused systems explicitly address infrastructure failures through protocol diversity.

The AWCT (Always Connected Things) framework [12] orchestrates LPWAN (LoRa/LoRaWAN) with ad-hoc networks (Bluetooth and Wi-Fi) specifically for standby emergency communication. Their architecture adds three modules to standard IoT devices (Raspberry Pi boards, in their test case): a battery module for power management, a power interrupt handler that triggers emergency mode when the power grid fails, and an ad-hoc bridge that forwards packets between the Bluetooth, Wi-Fi and LPWAN interfaces.

The system leverages dense IoT device deployment to provide emergency coverage, demonstrating that existing infrastructure can still serve a purpose during scenarios where the main power grid suffers issues.

However, AWCT's reliance on centralized LoRaWAN gateways for Internet connectivity creates a single point of failure when those gateways become unreachable.

A more comprehensive heterogeneous approach is presented in [18], which integrates HF radio (NVIS), satellite links, wireless sensor networks (WSNs), and delay-tolerant networking (DTN) with mobile drones for disaster monitoring. Their system uses RPL (Routing Protocol for Low-Power and Lossy Networks) [26] with three separate instances to differentiate traffic by priority: human data (voice/text via Bluetooth) receives the highest priority, followed by drone-collected data and finally sensor data.

The NVIS backhaul provides 250 km coverage radius without line-of-sight requirements, offering a cost-effective alternative to satellite communications.

While demonstrating successful real-world validation in Antarctica and urban deployments, the architecture's core NVIS topology with centralized coordination contrasts fully distributed operational requirements. Furthermore, their WSN layer requires a minimum 20-second sending interval to maintain acceptable packet loss rates at 10 hops, which highlights throughput limitations of single-channel tree topologies.

Security-focused multi-channel approaches like MCSC-WoT [3] combine AES encryption with dynamic channel hopping across 2.4 GHz Wi-Fi channels to defend against jamming and eavesdropping attacks. Their lightweight synchronization mechanism minimizes energy consumption while maintaining security through Frequency Hop Spread Spectrum (FHSS) patterns generated via PRNG. Nodes that lose synchronization can rejoin by hopping to random channels and waiting for the next synchronization signal.

However, the system depends on a master node broadcasting synchronization signals and uses an initial PRNG seed shared among all nodes, raising questions about scalability

and seed distribution mechanisms – particularly how new nodes can acquire seeds if deployed to a network at a later time.

### 2.1.2 Protocol Heterogeneity on Embedded Platforms

The work presented in [9] shows the technical feasibility of multi-protocol operation on commodity Wi-Fi/BLE modules by integrating ESP-NOW, ZigBee, and Modbus protocols on devices from the ESP32 family to construct multi-hop, tree-based wireless networks.

Their implementation uses BLE advertising beacons for neighbor discovery with RSSI measurements (for distance estimation), computing parent selection priorities based on weighted combinations of child count, RSSI values, and hop count in the network tree of a given node. The system also supports automatic parent reselection when the current parent becomes unreachable, making it somewhat resilient to single node failures.

Testing demonstrated successful multi-hop operation up to 5 hops in office environments, but evaluation was limited to linear network topologies. Additionally, this architecture relies on a tree topology with master-slave communication that is centered around a gateway (coordinator) rather than being a peer-to-peer mesh, creating a single point of failure at the coordinator node.

### 2.1.3 Runtime Adaptive Protocol Selection

A recent approach to protocol adaptation is presented in [29], which introduces a closed-loop control system with four integrated components: a context monitor sampling runtime metrics at 1 Hz, a decision engine using multi-criteria weighted scoring across six dimensions (message frequency, payload size, network conditions, packet loss rate, energy budget, QoS requirements), protocol adapters encapsulating protocol-specific libraries, and a learning component that adjusts thresholds using EWMA (Exponentially Weighted Moving Average) for deployment-specific patterns.

Some key aspects of this work include hysteresis control with a threshold band to prevent oscillation between protocols, and switching cost awareness requiring benefits to exceed costs by a certain threshold before transitioning.

Their evaluation comparing MQTT, CoAP, and HTTP revealed a significant discovery: receivers consistently consume 15-20% more energy than senders across all protocols, shifting the energy bottleneck from endpoint sensors to intermediary nodes like gateways. This receiver energy asymmetry has direct implications for gateway power management in disaster scenarios where battery replacement becomes impossible. The framework achieved 34% energy reduction versus static HTTP, 23% versus static MQTT, and 18% versus static CoAP, while requiring 85% less computation than machine learning approaches.

However, this framework assumes infrastructure availability for protocol endpoints (MQTT brokers, HTTP servers, CoAP endpoints) and was evaluated only on laptop platforms using Python libraries rather than embedded C implementations.

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Nevertheless, the evaluation methodology provides valuable insight into the energy expenditure of these different approaches, and grants useful foundations for more complex multi-protocol approaches, in particular with the multi-criteria decision framework and hysteresis control mechanism, but the actual system cannot operate when infrastructure fails.

The MINOS platform [24] exemplifies the limitations of centralized multi-protocol approaches. While providing sophisticated multi-protocol support (CORAL-SDN and Adaptable-RPL) with dynamic protocol deployment and real-time parameter tuning, the system depends fundamentally on a centralized SDN controller, MQTT broker, and web server infrastructure. The architecture's single point of failure means that when the controller becomes unreachable the entire system loses its adaptive capabilities and reverts to static operation at best, or complete failure at worst.

#### 2.1.4 MicroBabel's Approach

These limitations are addressed through opportunistic multi-protocol operation (BLE + Wi-Fi + LoRa + ESP-NOW) wherein devices adaptively select communication mediums based on factors like message priority, neighbor availability, energy budget, network conditions and device capabilities.

The system employs decentralized protocol selection without requiring SDN controllers or infrastructure coordination, instead using local decision-making informed by neighborhood information gathered through gossip protocols.

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Hysteresis control mechanisms adapted from the Adaptive Protocol Selection Framework prevent oscillations in these decisions while allowing rapid response to changing conditions.

Protocol-specific compression strategies account for the different energy/bandwidth trade-offs across the proposed stack (e.g. aggressive compression for (relatively) energy-expensive LoRa, lighter compression for short-range BLE), integrating the receiver energy asymmetry observations into power management decisions.

Unlike AWCT's LoRaWAN gateway dependency, Heterogeneous IoT's NVIS centralized backhaul, MCSC-WoT's master-based synchronization, or MINOS's SDN controller requirement, **MicroBabel** operates autonomously in a peer-to-peer manner with no static coordinator dependencies.

The multi-protocol capability provides resilience through diversity rather than optimization through centralized selection: when conditions render one medium unsuitable, devices autonomously transition to alternatives without requiring coordinator intervention.

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## 2.2 Peer-to-Peer Mesh Networking and Topology Management

Infrastructure-dependent star topologies in which devices communicate via a central coordinator or gateway suffer from a similar fate to single-protocol communication: when that coordinator becomes unavailable or unreachable, the entire network loses connectivity.

This pattern pervades current IoT deployments, from Wi-Fi access point dependencies to LoRaWAN gateway requirements, and becomes catastrophic in disaster scenarios where central coordinators are most likely to fail first.

Peer-to-peer (P2P) mesh architectures address this limitation by distributing coordination across all participating nodes, thus eliminating single points of failure. Nonetheless, achieving robust mesh operation requires solving three interconnected challenges: neighbor discovery and establishment of initial connectivity, topology maintenance as nodes join/leave a network, and efficient data routing through multi-hop paths when direct communication becomes impossible or inefficient.

### 2.2.1 Peer Discovery and Topology Maintenance

As discussed in Section 2.1.2, the Multi-Protocol IoT Gateway implementation [9] demonstrates BLE-based neighbor discovery with RSSI measurements for proximity estimation.

While that work focuses on multi-protocol integration, its topology management reveals a limitation of its tree-based approach: the system implements automatic parent reselection when coordinators fail, but the underlying tree structure imposes that nodes can only communicate through their parent-child relationships rather than arbitrary peer connections.

This restriction limits route diversity and resilience, creating dependency chains where a single intermediate node failure can disconnect entire subtrees.

A more sophisticated approach to membership management is presented in HyParView [11], in which each node maintains two distinct partial views for scalability: a small active view ( $\text{size} = \text{fanout} + 1$ ) containing nodes with which symmetric links are actively maintained, and a larger passive view serving as a backup pool of potential neighbors that may be promoted to the active view if one of its nodes fails.

The active view is managed reactively, such that nodes are added during join operations and removed upon failure detection, while the passive view is maintained cyclically through periodic shuffle operations that exchange node identifiers between peers.

This hybrid strategy enables remarkable resilience, with the system recovering from 80% node failures with minimal reliability loss (maintaining 95% reliability) and from 50% failures in just 1-2 membership cycles, compared to 60+ cycles required by purely cyclic protocols like Cyclon [25].

HyParView's deterministic flooding approach, by broadcasting messages along the entire active view graph rather than probabilistic neighbor selection, enables fast failure

detection since every active link is tested at each broadcast. The symmetric link requirement ensures bidirectionality: if node A can reach node B, then B can reach A, preventing the formation of one-way communication paths that complicate routing.

However, HyParView assumes TCP availability for maintaining persistent connections and using connection failures as implicit failure detectors. This dependency on full network stack functionality makes direct application to resource-constrained embedded platforms challenging, though the architectural principles of hybrid views and shuffle-based passive view maintenance remain valuable.

The heterogeneous disaster IoT architecture discussed in Section 2.1.1 employs RPL for its WSN layer, demonstrating practical routing in resource-constrained disaster scenarios.

Their performance analysis reveals considerable trade-offs: convergence time scales linearly from 7 seconds for 20 nodes to 14.5 seconds for 100 nodes, while packet loss ratio (PLR) at 10 hops reaches 80% with a 10-second sending interval but becomes acceptable at 20-second intervals.

These measurements highlight the throughput limitations imposed by tree topologies, in that their Instance 1 traffic (human data) must be restricted to 1-hop from the root node to ensure the least possible delay in its delivery, defeating the purpose of multi-hop mesh for critical communications.

The DTN component using mobile drones as data mules provides an alternative path for partitioned networks, with a maximum of 20 nodes per DODAG (destination-oriented directed acyclic graph) to maintain acceptable convergence times during emergency situations, but this approach trades latency for eventual delivery rather than real-time mesh routing.

### 2.2.2 Routing in Partitioned and Intermittently Connected Networks

When network partitions prevent end-to-end paths, store-and-forward mechanisms enable eventual data delivery. The Bundle Protocol [20] addresses delay-tolerant networking through custody-based retransmission and opportunistic connectivity exploitation. While the protocol specification predates modern IoT deployments and was not designed specifically for resource-constrained devices, its core principles inform contemporary DTN approaches.

The framework presented in [16] implements elastic bandwidth utilization by dynamically adjusting transmission rates based on available connectivity, and supports scheduled, predicted, and opportunistic transmission windows, taking inspiration from the Bundle Protocol.

Data parcels are compressed, encrypted, and bundled before transmission, with a load balancer managing concurrent transfer threads to optimize bandwidth usage during brief connectivity windows.

While their HTTP-based implementation targets cloud-backed IoT deployments, the core concepts of parceling data, maintaining transmission queues, and opportunistic forwarding during connectivity windows translate to peer-to-peer scenarios where aggregation nodes become neighbors in a mesh network.

### 2.2.3 Limitations of Centralized Coordination

The work on Resilient Edge-enable IoT [4] addresses coordinator failures through dynamic leader election and backup mechanisms within their framework.

Their coordination model divides environments into collaboration areas, with resource-rich edge devices serving as coordinators that allocate tasks to workers under their supervision when problems arise. Workers, in turn, are *active agents* such as robots and IoT devices that reside in a particular environment, detect problems, and notify their coordinators.

When coordinators fail, the system automatically elects backups through adaptive decentralized consensus, providing "gentle degradation" during failures with restoration after recovery. Multiple coordinators operate independently, eliminating single points of failure within the coordination model itself.

This architecture depends fundamentally on edge servers running JVM-based SCAFI middleware (a Scala library) to execute the aggregate programs that specify coordination behavior, and these heavyweight infrastructure requirements – both the Java runtime environment and resource-rich edge computing nodes – conflict with embedded platform constraints and infrastructure-failure scenarios.

While the aggregate computing paradigm separates concerns (sensing, actuation, communication, coordination), the implementation assumptions make it unsuitable for disaster-resilient systems where edge servers may be the infrastructure that fails. The formal guarantees of self-stabilization and compositional properties come at the cost of persistent computational infrastructure that an embedded-focused deployment cannot provide.

### 2.2.4 MicroBabel's Approach

**MicroBabel** intends to address these limitations through a fully distributed peer-to-peer mesh architecture without coordinator dependencies. The system adapts HyParView's hybrid view concept (maintaining small active neighbor sets for actual communication and larger passive backup lists for failure recovery) but implements discovery and maintenance using **TODO: BLE, LoRa...?** rather than TCP connections, accommodating the connectionless nature of embedded radio/wireless communication.

Neighbor discovery combines **TODO: BLE, LoRa...?** advertising beacons (carrying node identity, capabilities, and current neighbor counts, **TODO: mais coisas?**) with periodic gossip exchanges that propagate topology information beyond single-hop radio range.

queremos min-  
gle com o Ba-  
bel... se calhar  
não entrar por  
aqui ou tudo  
bem porque  
não vamos  
usar os big-  
babeis para  
coordination?

This multi-mechanism approach mitigates potential range limitations: while BLE typically provides 10-50m coverage depending on environment and antenna configuration, gossip-based propagation enables nodes to learn about distant neighbors through multi-hop dissemination, supporting informed routing decisions and topology adaptation.

Unlike the tree topology of Multi-Protocol Gateway or the RPL DODAG structure of heterogeneous disaster architecture, **MicroBabel** will implement true peer-to-peer mesh networking where any node can communicate with any other node through dynamically selected multi-hop paths.

Route selection considers multiple factors gathered through local observation and gossip: link quality metrics (RSSI, packet success rates), neighbor availability across different protocols, and current energy budgets.

Store-and-forward mechanisms inspired by Bundle Protocol will enable operation during network partitions, but will be adapted for peer-to-peer rather than cloud-centric operation: data parcels are compressed (using techniques from Section 2.4), queued in local storage (flash, MicroSD cards) when no forward path exists, and opportunistically transmitted when connectivity windows emerge, be it through topology changes or protocol switching creating new communication opportunities.

Coordination emerges from local interactions via gossip-based information propagation, decentralized time synchronization (Section 2.3), and adaptive protocol selection (Section 2.1), rather than centralized allocation of roles.

## 2.3 Decentralized Synchronization and Time Coordination

## 2.4 Lightweight Data Compression and Energy Efficiency

## 2.5 Security and Privacy for Resource-Constrained Emergency Communication

## 2.6 Folder and Files

The NOVAtesis L<sup>A</sup>T<sub>E</sub>X (*novathesis*) template is organized into many files and folders. At the main level it includes the following files and folders listed in Table 2.1.

Table 2.1: The folders and files (top level).

Name	Type	Access	Contents
------	------	--------	----------

<code>template.tex</code>			The main template file. You need to <i>compile</i> this file with one of pdfLATEX, XELATEX, or LuaLATEX to obtain the PDF file ("template.pdf"). I recommend the usage of the "latexmk" command or, if you use a UN*X-like OS, you may use "make" (and the given "Makefile").
<code>Config</code>			Configuration files. Please customize your template by changing the files in this folder!
<code>Chapters</code>			Examples of document contents, including Chapters, Appendices, Annexes, Abstracts, Glossaries, Lists of Symbols, etc. Replace them with your own.
<code>Bibliography</code>			Where all your bibliography files should be located. You may have many bibliography files as you want.
<code>template.pdf</code>			A possible result of applying pdfLATEX to the "template.tex" file. The look and feel of the document will depend on the parametrization/configuration (e.g., School) of this template.
<code>novathesis.cls</code>			The main class file.
<code>NOVAthesisFiles</code>			Additional files for the <code>novathesis</code> template. This is where all the juice is so, unless you are a LATEXmagician, don't mess up with the files and folders inside this folder.

Table 2.2: The configuration files (Config folder).

Name	Type	Access	Contents
<code>0_memoir.tex</code>			Options specific for the <code>memoir</code> class. <i>Don't touch this file unless you know what you are doing!</i>
<code>1_novathesis.tex</code>			The main configuration file for the template, e.g., select the document type, the school, the used languages, etc.
<code>2_biblatex.tex</code>			Select how your citations and bibliographic references will be printed. The default is numbers inside square brackets, e.g. [13], but you can change it to other formats, such as author-year, e.g., Lourenço (2021).

<code>3_cover.tex</code>			Configure cover contents (e.g., author's name, thesis/dissertation title, author, advisers, committee, etc)
<code>4_files.tex</code>			Select which files shall be included in the document as chapters, appendices, annexes, etc...
<code>5_packages.tex</code>			User's customization, such as loading additional packages and declare user defined commands.
<code>6_list_of.tex</code>			Configure the lists to be printed (table of contents, list of figures, list of tables, list of listings, etc). <i>Don't touch this file unless you know what you are doing!</i>
<code>9_nova_fct.tex</code>			Configurations specific to NOVA FCT. <i>Otherwise ignored.</i>
<code>9_ulisboa_fmv.tex</code>			Configurations specific to ULISBOA FMV. <i>Otherwise ignored.</i>
<code>9_ulisboa_ist.tex</code>			Configurations specific to ULISBOA IST. <i>Otherwise ignored.</i>
<code>9_uminho.tex</code>			Configurations specific to UMINHO (all schools). <i>Otherwise ignored.</i>

## 2.7 Customizing the *novathesis* template

The *novathesis* template can be customized by editing the files in the Config folder.

### 2.7.1 Options in `1_novathesis.tex`

#### 2.7.1.1 Most Relevant Options (`1_novathesis.tex`)

<b>doctype=OPT</b> <i>phd, phdprop, phdplan, msc, mscplan, bsc, plain</i>	<b>The type of the document.</b> phd → PhD thesis (← default). phdprop → PhD thesis proposal (for FCT-NOVA). phdplan → PhD thesis plan. msc → MSc thesis. mscplan → MSc thesis plan. bsc → BSc report. plain → Other report.
--	---

**school=OPT**

*nova/fct, nova/fcsh, nova/ims,  
nova/ims/mcsig, nova/ims/mgt,  
nova/ensp, nova/itqb/green,  
nova/itqb/gray, ulisboa/ist, ulisboa/fcul,  
ulisboa/fmv, uminho/eaad, uminho/ec,  
uminho/ed, uminho/eeg, uminho/eeng,  
uminho/elach, uminho/emed,  
uminho/epsi, uminho/ese, uminho/i3bs,  
uminho/ics, uminho/ie, iscteiul/eta,  
ips/ests, ipl/isel, ipl/isel/meb, ulht/deisi,  
ulht/mge, other/esep*

---

**Selection of the university and of the school (and degree variant).**

⇒ Default: `school=nova/fct`

This option changes the typesetting of the de document to some specific School formating and layout, like covers, margins, fonts, paragraph spacing and indentation, etc.

**docstatus=OPT**

*draft, provisional, final*

**The current status of the document.**

*working* → Working version (⇐ default).

*provisional* → Version for submission.

*final* → Final version.

---

**lang=OPT**

*en, pt, de, es, fr, gr, it*

**The main language for the document.**

*en* → English (⇐ default).

*pt* → Portuguese.

*de* → German.

*es* → Spanish.

*fr* → French.

*gr* → Greek.

*it* → Italian.

---

**media=OPT**

*screen, paper*

**The target media for the PDF.**

*screen* → No empty/white pages (⇐ default).

*paper* → Empty/white pages are added when necessary.

---

**print/webography=OPT**

*User defined title*

**Generate a separate bibliography for @online references.**

⇒ Default: `print/webography=undefined`

If undefined, the @online references are list in the main bibliography. If defined, the @online references will be printed in a separate bibliography titled as given in the option.

---

**color/links=OPT**

*Color name*

**The color for the hyperlinks (URLs, cross references, citations).**

⇒ Default: `color/links=DarkBlue`

The valid color names as listed in “xcolor” manual, the “svgnames” color set.

---

<b>color/gls=OPT</b>	<b>The color for the glossary managed hyperlinks (glossary, symbols, etc).</b>
<i>Color name</i>	 ⇒ Default: <code>color/gls=Black</code>
	The valid color names as listed in “xcolor” manual, the “svgnname” color set.
<b>print/index=OPT</b>	<b>Print the (words) index at the end of the document.</b>
<i>true,</i>	
<i>false</i> (← default)	Print the index (in Portuguese <i>Índice Remissivo</i> ).

### 2.7.1.2 Less Relevant Options (`1_novathesis.tex`)

<b>abstractorder=OPT</b>	<b>Forces the abstracts languages and order for documents in language <math>L_0</math>.</b>
$L_0 = \{L_1, L_2, \dots, L_n\}$	 ⇒ Default: <code>abstractorder={en={en,pt}}</code> for english ⇒ Default: <code>abstractorder={L={L,en}}</code> for lang $L$ $L_i$ is a two-letters language code from the set of valid language codes, following ISO 3166-1 (alfa-2).
<b>lang/extr=OPT</b>	<b>List of additional languages are used in the document besides the main laguage and those used in the abstracts (above).</b>
$\{L_1, L_2, \dots, L_n\}$	 ⇒ Default: <code>lang/extr={}</code> $L_i$ is a two-letters language code from the set of valid language codes, following ISO 3166-1 (alfa-2).
<b>gnumberlist=OPT</b>	<b>Shall the glossary entries list the page numbers where those entries are used? (Like a reverse index!)</b>
<i>true, (← default)</i>	
<i>false</i>	
<b>numberallpages=OPT</b>	<b>Shall all the pages (except cover) be numbered?</b>
<i>true,</i>	
<i>false</i> (← default)	
<b>tocintoc=OPT</b>	<b>Shall table of contents be listed in the table of contents?</b>
<i>true,</i>	
<i>false</i> (← default)	
<b>tocintoc=OPT</b>	<b>Shall a second cover page be forced?</b>
<i>true,</i>	If the contents for the second page are not defined, the second cover will be a replica of the first cover.
<i>false</i> (← default)	

<b>print/committee=OPT</b>	<b>Shall the evaluation committee be printed?</b>
<i>true,</i> <i>false</i>	⇒ Default: print/committee=true if docstatus=final ⇒ Default: print/committee=false otherwise
<hr/>	<hr/>
<b>print/frontmatter=OPT</b>	<b>Shall the front matter be printed?</b>
<i>true, (← default)</i> <i>false</i>	Set to false to generate a PDF with only the cover and the book chapters.
<hr/>	<hr/>
<b>print/statement=OPT</b>	<b>Shall the honor/originality statement be printed?</b>
<i>true,</i> <i>false (← default)</i>	
<hr/>	<hr/>
<b>print/copyright=OPT</b>	<b>Shall the copyright message be printed?</b>
<i>true, (← default)</i> <i>false</i>	
<hr/>	<hr/>
<b>print/timestamp=OPT</b>	<b>Shall a timestamp (with the PDF generation date/time) be printed in the cover?</b>
<i>true,</i> <i>false</i>	⇒ Default: print/timestamp=true if docstatus=working ⇒ Default: print/timestamp=false otherwise
<hr/>	<hr/>
<b>style/url=OPT</b>	<b>Use the same (main) font in URLs?</b>
<i>default, (← default)</i> <i>same</i>	
<hr/>	<hr/>
<b>style/font=OPT</b>	<b>Which font set to use in the document?</b>
<i>arial, bookman, calibri, erewhon, kieranhealy, kpfonts, libertine, newpx, newsgott, scholax</i>	arial → Use ‘arial’ font. Requires Xe <sup>L</sup> A <sub>T</sub> E <sub>X</sub> or Lua <sup>L</sup> A <sub>T</sub> E <sub>X</sub> . bookman → Use ‘bookman’ font. calibri → Use ‘calibri’ font. Requires Xe <sup>L</sup> A <sub>T</sub> E <sub>X</sub> or Lua <sup>L</sup> A <sub>T</sub> E <sub>X</sub> . erewhon → Use ‘erewhon’ font. kieranhealy → Use ‘kieranhealy’ font. kpfonts → Use ‘palatino’ font. libertine → Use ‘libertine’ font. newpx → Use ‘palatino’ font. (← default) newsgott → Use ‘newsgott’ font. Requires Xe <sup>L</sup> A <sub>T</sub> E <sub>X</sub> or Lua <sup>L</sup> A <sub>T</sub> E <sub>X</sub> . scholax → Use ‘scholax’ font.

**style/chapter=OPT**

See list on the side!

**Which chapter style to use in the document?**

Besides the standard `memoir` chapter styles (`default`, `section`, `article`, `reparticle`, `hangnum`, `companion`, `demo`, `bianchi`, `bringhurst`, `brotherton`, `chappell`, `culver`, `dash`, `demodemoell`, `ger`, `lyhne`, `madsen`, `pedersen`, `southall`, `thatcher`, `veelo`, `verville`, `crosshead`, `dowding`, `komalike`, `ntglike`, `tandh`, `wilsondob`), the customized list of chapter styles below is also available.

<code>bar</code>	→ Use ‘ <code>bar</code> ’ chapter style. ( $\Leftarrow \text{default}$ )
<code>bar-compact</code>	→ Use ‘ <code>bar-compact</code> ’ chapter style.
<code>bluebox</code>	→ Use ‘ <code>bluebox</code> ’ chapter style.
<code>compact</code>	→ Use ‘ <code>compact</code> ’ chapter style.
<code>elegant</code>	→ Use ‘ <code>elegant</code> ’ chapter style.
<code>fmv</code>	→ Use ‘ <code>fmv</code> ’ chapter style.
<code>hansen</code>	→ Use ‘ <code>hansen</code> ’ chapter style.
<code>ist</code>	→ Use ‘ <code>ist</code> ’ chapter style.
<code>ist2</code>	→ Use ‘ <code>ist2</code> ’ chapter style.
<code>pedersen</code>	→ Use ‘ <code>pedersen</code> ’ chapter style.

---

**lang/cover=OPT**

*en, pt, de, es, fr, gr, it*

**The main language for the cover.**

⇒ Default: *The same as the main language*.

**lang/copyright=OPT**

*en, pt, de, es, fr, gr, it*

**The main language for the copyright message.**

⇒ Default: *The same as the main language*.

**spine/layout=OPT**

*no, full, trim*

**Print the “book spine” at the end of the document?**

⇒ Default: ‘`trim`’ if `docstatus=final`

⇒ Default: ‘`no`’ otherwise

`no` → do not print the book spine.

`full` → print the book spine in a full page.

`trim` → print and trim the page to the width of the book spine.

---

**spine/width=OPT**

$\text{\LaTeX}$  dimension

**Force the width of the “book spine”.**

⇒ Default: *The “natural width”*.

The default width for the book spine will be the width of the number of pages of the document if printed in standard paper ( $80\text{g}/\text{m}^2$ ).

**debug=OPT**

*cover, spine*

**Activate debug mode for cover and/or book spine.**

⇒ Default: `debug={}`

## 2.8 How to Write Using L<sup>A</sup>T<sub>E</sub>X

Please have a look at Chapter 3, where you may find many examples of L<sup>A</sup>T<sub>E</sub>X constructs, such as Sectioning, inserting Figures and Tables, writing Equations, Theorems and algorithms, exhibit code listings, etc.

## 2.9 Example glossary, acronyms, and symbols

This is the first occurrence of an abbreviation: abbreviation of a longer text (abbrev). And now the second occurrence of the same abbreviation: abbrev. And a new acronym with capital letter: And extension of a xpto (xpto) and reused xpto. Let's also use a few other acronyms such as acronym aaa (aaa), acronym aab (aab), acronym aba (aba), acronym bbb (bbb) and xpto. In geometry, the area enclosed by a circle of radius  $r$  is  $\pi r^2$ . Here the Greek letter  $\pi$  is equal to the ratio of the circumference of any circle to its diameter. Lets add "computer" to the glossary! Be carefull with mathematical symbols in acronyms, please see the definition of  $\mu$ .

# A SHORT LATEX TUTORIAL WITH EXAMPLES

This Chapter aims at exemplifying how to do common stuff with LATEX. We also show some stuff which is not that common! ;)

Please, use these examples as a starting point, but you should always consider using the *Big Oracle* (aka, [Google](#), your best friend) to search for additional information or alternative ways for achieving similar results.

## 3.1 Document Structure

## 3.2 Dealing with Bibliography

Citing something online [[wiki:shuntingyard](#), [flex](#), [bison](#)].

## 3.3 Inserting Tables

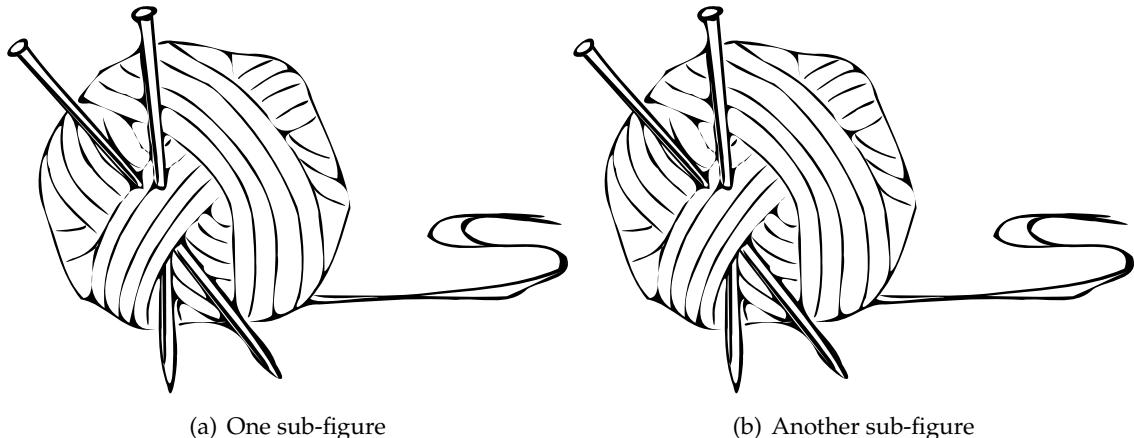
## 3.4 Importing Images

## 3.5 Floats, Figures and Captions

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.



(a) One sub-figure

(b) Another sub-figure

Figure 3.1: A figure with two sub-figures!

And this is a small text that references the Figure 3.1 and its Subfigures 3.1(a) and 3.1(b).

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan

eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

## 3.6 Text Formatting

## 3.7 Generating PDFs from L<sup>A</sup>T<sub>E</sub>X

### 3.7.1 Generating PDFs with pdflatex

You may create PDF files either by using `latex` to generate a DVI file, and then use one of the many DVI-2-PDF converters, such as `dvipdfm`.

Alternatively, you may use `pdflatex`, which will immediately generate a PDF with no intermediate DVI or PS files. In some systems, such as Apple, PDF is already the default format for L<sup>A</sup>T<sub>E</sub>X. I strongly recommend you to use this approach, unless you have a very good argument to go for `latex + dvipdfm`.

A typical pass for a document with figures, cross-references and a bibliography would be:

```
$ pdflatex template  
$ bibtex template  
$ pdflatex template  
$ pdflatex template
```

You will notice that there is a new PDF file in the working directory called `template.pdf`. Simple :)

Please note that, to be sure all table of contents, cross-references and bibliographic citations are up-to-date, you must run `latex` once, then `bibtex`, and then `latex` twice.

### 3.7.2 Dealing with Images

You may process the same source files with both `latex` or `pdflatex`. But, if your text include images, you must be careful. `latex` and `pdflatex` accept images in different (exclusive) formats. For `latex` you may use EPS ou PS figures. For `pdflatex` you may use JPG, PNG or PDF figures. I strongly recommend you to use PDF figures in vectorial format (do not use bitmap images unless you have no other choice).

### 3.7.3 Dealing with Citations

Para fazer citações, deverá usar-se a chave da referência no ficheiro BibTeX. Se for uma única referência [Artho04], usar um “~” para ligar o `\cite{...}` à palavra que o precede (... referência~`\cite{Artho04}`). Caso queira fazer múltiplas citações [Shavit95, Silberschatz06, Moss85], deverá agrupá-las dentro de um único `\cite{...}`.

Note que o ficheiro de bibliografia pode ter tantas entradas quantas quiser. Apesar das aquelas cuja chave seja referenciada no texto é que serão incluídas na listagem de bibliografia.

### 3.7.4 Footnotes

Footnotes<sup>1</sup> will be numbered and shown in the bottom of the page.

### 3.7.5 Tables

The Table 3.1 illustrates some important concepts associated with table construction:

- i) Do not use vertical lines;
- ii) The caption should be above the table;
- iii) Use the macros `\toprule`, `\midrule` and `\bottomrule` to make the top, inner and bottom horizontal lines, respectively.

Table 3.1: Test results summary.

Test	Anomalies	Warnings	Correct	Categories	Missed
Connection [Beckman08]	2	2	1	C	1
Coordinates'03 [Artho03]	1	4	1	2B, 1C	0
Local Vari- able [Artho03]	1	2	1	A	0
NASA [Artho03]	1	1	1	—	0
Coordinates'04 [Artho04]	1	4	1	3C	0
Buffer [Artho04]	0	7	0	2A, 1B, 2C, 2D	0
Double- Check [Artho04]	0	2	0	1A, 1B	0

---

<sup>1</sup>This is a simple footnote.

StringBuffer [Flanagan0·	1	0	0	—	1
Account [Praun03]	1	1	1	—	0
Jigsaw [Praun03]	1	2	1	C	0
Over-reporting [Praun03]	0	2	0	1A, 1C	0
Under-reporting [Praun03]	1	1	1	—	0
Allocate Vector [IBM-Rep]	1	2	1	C	0
Knight Moves [Beckman08]	1	3	1	2B	0
Total	12	33	10	5A, 6B, 10C, 2D	2

### 3.7.6 Figures

The images inserted in the document must be of good quality, preferably in vector format (vector PDF) and not in *bitmap* (PNG, JPG, etc.). *bitmap* images (Figure 3.2) do not scale well and have negative effects on the quality of your document. On the other hand, *vector* images Figure 3.3 scale as much as necessary without degrading the quality of the image.

You should only use *screenshots* for your plots, charts, etc, if you absolutely have no other alternative. Instead of generating a *screenshot*, try using a virtual PDF printer and printing to a PDF file. As a general rule, you will get a vector PDF. Even if your PDF contains images, they will always be of higher or equal quality than what you would get with a *screenshot*.

To combine several figures into a single one... You can then reference the set as Figure 3.4 or the sub-figures separately as 3.4() and 3.4(a).

## 3.8 Equations

LaTeX is a powerful tool for writing in a mathematical style. It allows you to insert formulas into the text, such as this:  $ax^2 + bx + c = 0$ . It also allows formulas to be highlighted on a separate line and centered on the page.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

or numbererd

$$e = mc^2 \tag{3.1}$$

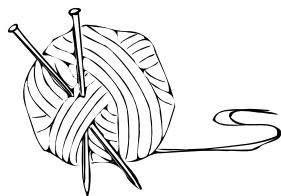
which can latter be referenced as equation 3.1



Figure 3.2: Bitmap image (JPG/PNG)



Figure 3.3: Vectorial image (PDF)



(a) Novelo de lã



(b) Tempestade com neve

Figure 3.4: Exemplo de utilização de *subbottom*

### 3.9 Test for listings

Testing the package “listings”...

Listing 3.1: cap

```
1 if(a==b)
2   puts("YESS !")
```

### 3.10 Test for algorithms

Uncomment the algorithms source below and add the following to file “5\_packages.tex”

```
\usepackage{algorithm2e}
\RestyleAlgo{ruled}
```

and uncomment

```
\ntaddlistof{listofalgorithms}
```

in file “8\_list\_og.tex”.

## ADDING SUPPORT TO A NEW SCHOOL (WORK IN PROGRESS)

My advice to customize the `novathesis` template to another School/University/Department/Degree is to browse the existing supported degrees to find one that is *close enough*, and depart from there!

The multitude of layouts supported by the `novathesis` template is based in a three-tier naming scheme, separated by slashes: University / School / Department-or-Degree. This three-tier naming scheme is also reflected in a three-tier directory (folder) structure in: `<project_root>a/NOVAthesiFiles/Schools/....` For example:

```

...
|
+-- nova
|   +-- Images
|   +-- fct
|   |   \-- Images
|   +-- ims
|   |   \-- Images
|   ...
|
\-- uminho
    +-- Images
    +-- ea
    |   \-- Images
    +-- ec
    |   \-- Images
    ...

```

The directory `uminho` contains the customization for all Schools of Universidade do Minho. This university is an example of the case where the regulations are defined at

University level and all the schools apply the same thesis layout and organization. So, the all the customization is done in the file `uminho/uminho-defaults.1df`, except the definition of the name and logo of each individual school.

As another example, the directory `nova` contains the customization for all Schools from NOVA University Lisbon. This university grants a lot of freedom in the definition of the thesis layouts. In some cases, they are defined at the School level (e.g., NOVA FCT), while in some other cases they are defined separately for each degree (e.g., NOVA IMS).

1. Try all the already supported schools and check which one is closer to your needs;
  - a) Edit `Config/1_novathesis.tex` and near line 28 uncomment the line with key  
`\ntsetup{school=<SOMETHING>};`
  - b) For each school supported (see the comment), replace `<SOMETHING>` with the school name, e.g., make it `\ntsetup{school=ulisboa/fmv}`
  - c) Recompile and check the document. Particularly, check the cover layout, the front-page (second cover) layout, the front-matter contents, the bibliography style;
  - d) Repeat for the next school, until you find one close enough.
- 2.

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# A

## NOVATHESIS COVERS SHOWCASE

This Appendix shows examples of covers for some of the supported Schools. When the Schools have very similar covers (e.g., all the schools from Universidade do Minho), just one cover is shown. If the covers for MSc dissertations and PhD thesis are considerable different (e.g., for FCT-NOVA and UMinho), then both are shown.

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imperdiet sit amet, quam. Quisque scelerisque dapibus nibh. Nam enim. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nunc ut metus. Ut metus justo, auctor at, ultrices eu, sagittis ut, purus. Aliquam aliquam.

## A.1 A section here

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Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetur adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

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eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetur.

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

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Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Donec odio elit, dictum in, hendrerit sit amet, egestas sed, leo. Praesent feugiat sapien aliquet odio. Integer vitae justo. Aliquam vestibulum fringilla lorem. Sed neque lectus, consectetur at, consectetur sed, eleifend ac, lectus. Nulla facilisi. Pellentesque eget lectus. Proin eu metus. Sed porttitor. In hac habitasse platea dictumst. Suspendisse eu lectus. Ut mi mi, lacinia sit amet, placerat et, mollis vitae, dui. Sed ante tellus, tristique ut, iaculis eu, malesuada ac, dui. Mauris nibh leo, facilisis non, adipiscing quis, ultrices a, dui.

Morbi luctus, wisi viverra faucibus pretium, nibh est placerat odio, nec commodo wisi enim eget quam. Quisque libero justo, consectetur a, feugiat vitae, porttitor eu, libero. Suspendisse sed mauris vitae elit sollicitudin malesuada. Maecenas ultricies eros sit amet ante. Ut venenatis velit. Maecenas sed mi eget dui varius euismod. Phasellus aliquet volutpat odio. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Pellentesque sit amet pede ac sem eleifend consectetur. Nullam elementum, urna vel imperdiet sodales, elit ipsum pharetra ligula, ac pretium ante justo a nulla. Curabitur tristique arcu eu metus. Vestibulum lectus. Proin mauris. Proin eu nunc eu urna hendrerit faucibus. Aliquam auctor, pede consequat laoreet varius, eros tellus scelerisque quam, pellentesque hendrerit ipsum dolor sed augue. Nulla nec lacus.

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Etiam euismod. Fusce facilisis lacinia dui. Suspendisse potenti. In mi erat, cursus id, nonummy sed, ullamcorper eget, sapien. Praesent pretium, magna in eleifend egestas, pede pede pretium lorem, quis consectetur tortor sapien facilisis magna. Mauris quis magna varius nulla scelerisque imperdierat. Aliquam non quam. Aliquam porttitor quam a lacus. Praesent vel arcu ut tortor cursus volutpat. In vitae pede quis diam bibendum placerat. Fusce elementum convallis neque. Sed dolor orci, scelerisque ac, dapibus nec, ultricies ut, mi. Duis nec dui quis leo sagittis commodo.

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Etiam ac leo a risus tristique nonummy. Donec dignissim tincidunt nulla. Vestibulum rhoncus molestie odio. Sed lobortis, justo et pretium lobortis, mauris turpis condimentum augue, nec ultricies nibh arcu pretium enim. Nunc purus neque, placerat id, imperdierat sed, pellentesque nec, nisl. Vestibulum imperdierat neque non sem accumsan laoreet. In hac habitasse platea dictumst. Etiam condimentum facilisis libero. Suspendisse in elit quis nisl aliquam dapibus. Pellentesque auctor sapien. Sed egestas sapien nec lectus. Pellentesque vel dui vel neque bibendum viverra. Aliquam porttitor nisl nec pede. Proin mattis libero vel turpis. Donec rutrum mauris et libero. Proin euismod porta felis. Nam lobortis, metus quis elementum commodo, nunc lectus elementum mauris, eget vulputate ligula tellus eu neque. Vivamus eu dolor.

Nulla in ipsum. Praesent eros nulla, congue vitae, euismod ut, commodo a, wisi. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Aenean nonummy magna non leo. Sed felis erat, ullamcorper in, dictum non, ultricies ut, lectus. Proin vel arcu a odio lobortis euismod. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Proin ut est. Aliquam odio. Pellentesque massa turpis, cursus eu, euismod nec, tempor congue, nulla. Duis viverra gravida mauris. Cras tincidunt. Curabitur eros ligula, varius ut, pulvinar in, cursus faucibus, augue.

Nulla mattis luctus nulla. Duis commodo velit at leo. Aliquam vulputate magna et leo. Nam vestibulum ullamcorper leo. Vestibulum condimentum rutrum mauris. Donec

id mauris. Morbi molestie justo et pede. Vivamus eget turpis sed nisl cursus tempor. Curabitur mollis sapien condimentum nunc. In wisi nisl, malesuada at, dignissim sit amet, lobortis in, odio. Aenean consequat arcu a ante. Pellentesque porta elit sit amet orci. Etiam at turpis nec elit ultricies imperdiet. Nulla facilisi. In hac habitasse platea dictumst. Suspendisse viverra aliquam risus. Nullam pede justo, molestie nonummy, scelerisque eu, facilisis vel, arcu.

Curabitur tellus magna, porttitor a, commodo a, commodo in, tortor. Donec interdum. Praesent scelerisque. Maecenas posuere sodales odio. Vivamus metus lacus, varius quis, imperdiet quis, rhoncus a, turpis. Etiam ligula arcu, elementum a, venenatis quis, sollicitudin sed, metus. Donec nunc pede, tincidunt in, venenatis vitae, faucibus vel, nibh. Pellentesque wisi. Nullam malesuada. Morbi ut tellus ut pede tincidunt porta. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam congue neque id dolor.

Donec et nisl at wisi luctus bibendum. Nam interdum tellus ac libero. Sed sem justo, laoreet vitae, fringilla at, adipiscing ut, nibh. Maecenas non sem quis tortor eleifend fermentum. Etiam id tortor ac mauris porta vulputate. Integer porta neque vitae massa. Maecenas tempus libero a libero posuere dictum. Vestibulum ante ipsum primis in faucibus orci luctus et ultrices posuere cubilia Curae; Aenean quis mauris sed elit commodo placerat. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Vivamus rhoncus tincidunt libero. Etiam elementum pretium justo. Vivamus est. Morbi a tellus eget pede tristique commodo. Nulla nisl. Vestibulum sed nisl eu sapien cursus rutrum.

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Nulla ac nisl. Nullam urna nulla, ullamcorper in, interdum sit amet, gravida ut, risus. Aenean ac enim. In luctus. Phasellus eu quam vitae turpis viverra pellentesque. Duis feugiat felis ut enim. Phasellus pharetra, sem id porttitor sodales, magna nunc aliquet nibh, nec blandit nisl mauris at pede. Suspendisse risus risus, lobortis eget, semper at, imperdiet sit amet, quam. Quisque scelerisque dapibus nibh. Nam enim. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Nunc ut metus. Ut metus justo, auctor at, ultrices eu, sagittis ut, purus. Aliquam aliquam.

# B

## APPENDIX 2 LOREM IPSUM

This is a test with citing something [ecoop12-dias] in the appendix.

AAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

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Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt

ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

Fusce mauris. Vestibulum luctus nibh at lectus. Sed bibendum, nulla a faucibus semper, leo velit ultricies tellus, ac venenatis arcu wisi vel nisl. Vestibulum diam. Aliquam pellentesque, augue quis sagittis posuere, turpis lacus congue quam, in hendrerit risus eros eget felis. Maecenas eget erat in sapien mattis porttitor. Vestibulum porttitor. Nulla facilisi. Sed a turpis eu lacus commodo facilisis. Morbi fringilla, wisi in dignissim interdum, justo lectus sagittis dui, et vehicula libero dui cursus dui. Mauris tempor ligula sed lacus. Duis cursus enim ut augue. Cras ac magna. Cras nulla. Nulla egestas. Curabitur a leo. Quisque egestas wisi eget nunc. Nam feugiat lacus vel est. Curabitur consectetur.

Suspendisse vel felis. Ut lorem lorem, interdum eu, tincidunt sit amet, laoreet vitae, arcu. Aenean faucibus pede eu ante. Praesent enim elit, rutrum at, molestie non, nonummy vel, nisl. Ut lectus eros, malesuada sit amet, fermentum eu, sodales cursus, magna. Donec eu purus. Quisque vehicula, urna sed ultricies auctor, pede lorem egestas dui, et convallis elit erat sed nulla. Donec luctus. Curabitur et nunc. Aliquam dolor odio, commodo pretium, ultricies non, pharetra in, velit. Integer arcu est, nonummy in, fermentum faucibus, egestas vel, odio.

Sed commodo posuere pede. Mauris ut est. Ut quis purus. Sed ac odio. Sed vehicula hendrerit sem. Duis non odio. Morbi ut dui. Sed accumsan risus eget odio. In hac habitasse platea dictumst. Pellentesque non elit. Fusce sed justo eu urna porta tincidunt. Mauris felis odio, sollicitudin sed, volutpat a, ornare ac, erat. Morbi quis dolor. Donec pellentesque, erat ac sagittis semper, nunc dui lobortis purus, quis congue purus metus ultricies tellus. Proin et quam. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos hymenaeos. Praesent sapien turpis, fermentum vel, eleifend faucibus, vehicula eu, lacus.

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## APPENDIX B. APPENDIX 2 LOREM IPSUM

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## APPENDIX B. APPENDIX 2 LOREM IPSUM

lobortis in, sodales eget, dui. Morbi ultrices rutrum lorem. Nam elementum ullamcorper leo. Morbi dui. Aliquam sagittis. Nunc placerat. Pellentesque tristique sodales est. Maecenas imperdiet lacinia velit. Cras non urna. Morbi eros pede, suscipit ac, varius vel, egestas non, eros. Praesent malesuada, diam id pretium elementum, eros sem dictum tortor, vel consectetur odio sem sed wisi.

# I

## ANNEX 1 LOREM IPSUM

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Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

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