JOÃO RICARDO BOGALHO BRILHA

BSc in Computer Science and Engineering

MICROBABEL

A MULTI-PROTOCOL APPROACH FOR RESILIENT AND DECENTRALIZED IOT NETWORKS

MICROBABEL

A MULTI-PROTOCOL APPROACH FOR RESILIENT AND DECENTRALIZED IOT NETWORKS

JOÃO RICARDO BOGALHO BRILHA

BSc in Computer Science and Engineering

Adviser: João Leitão
Associate Professor, NOVA University Lisbon

ABSTRACT

Regardless of the language in which the dissertation is written, usually there are at least two abstracts: one abstract in the same language as the main text, and another abstract in some other language.

The abstracts' order varies with the school. If your school has specific regulations concerning the abstracts' order, the NOVAthesis LaTeX (novathesis) (LaTeX) template will respect them. Otherwise, the default rule in the novathesis template is to have in first place the abstract in *the same language as main text*, and then the abstract in *the other language*. For example, if the dissertation is written in Portuguese, the abstracts' order will be first Portuguese and then English, followed by the main text in Portuguese. If the dissertation is written in English, the abstracts' order will be first English and then Portuguese, followed by the main text in English. However, this order can be customized by adding one of the following to the file `5_packages.tex`.

```
\ntsetup{abstractorder={<LANG_1>,...,<LANG_N>}}
\ntsetup{abstractorder={<MAIN_LANG>={<LANG_1>,...,<LANG_N>}}}
```

For example, for a main document written in German with abstracts written in German, English and Italian (by this order) use:

```
\ntsetup{abstractorder={de={de,en,it}}}
```

Concerning its contents, the abstracts should not exceed one page and may answer the following questions (it is essential to adapt to the usual practices of your scientific area):

1. What is the problem?

2. Why is this problem interesting/challenging?

3. What is the proposed approach/solution/contribution?

4. What results (implications/consequences) from the solution?

Keywords: One keyword · Another keyword · Yet another keyword · One keyword more · The last keyword

Resumo

Independentemente da língua em que a dissertação está escrita, geralmente esta contém pelo menos dois resumos: um resumo na mesma língua do texto principal e outro resumo numa outra língua.

A ordem dos resumos varia de acordo com a escola. Se a sua escola tiver regulamentos específicos sobre a ordem dos resumos, o template (LaTeX) novathesis irá respeitá-los. Caso contrário, a regra padrão no template novathesis é ter em primeiro lugar o resumo *no mesmo idioma do texto principal* e depois o resumo *no outro idioma*. Por exemplo, se a dissertação for escrita em português, a ordem dos resumos será primeiro o português e depois o inglês, seguido do texto principal em português. Se a dissertação for escrita em inglês, a ordem dos resumos será primeiro em inglês e depois em português, seguida do texto principal em inglês. No entanto, esse pedido pode ser personalizado adicionando um dos seguintes ao arquivo `5_packages.tex`.

```
\abstractorder(<MAIN_LANG>):={<LANG_1>,...,<LANG_N>}
```

Por exemplo, para um documento escrito em Alemão com resumos em Alemão, Inglês e Italiano (por esta ordem), pode usar-se:

```
\ntsetup{abstractorder={de={de,en,it}}}
```

Relativamente ao seu conteúdo, os resumos não devem ultrapassar uma página e frequentemente tentam responder às seguintes questões (é imprescindível a adaptação às práticas habituais da sua área científica):

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

CONTENTS

List of Figures

List of Tables

Listings

Glossary

This document is incomplete. The external file associated with the glossary 'main' (which should be called `template.gls`) hasn't been created.

Check the contents of the file `template.glo`. If it's empty, that means you haven't indexed any of your entries in this glossary (using commands like `\gls` or `\glsadd`) so this list can't be generated. If the file isn't empty, the document build process hasn't been completed.

You may need to rerun LaTeX. If you already have, it may be that TeX's shell escape doesn't allow you to run makeindex. Check the transcript file `template.log`. If the shell escape is disabled, try one of the following:

- Run the external (Lua) application:

  ```
  makeglossaries-lite "template"
  ```

- Run the external (Perl) application:

  ```
  makeglossaries "template"
  ```

Then rerun LaTeX on this document.

This message will be removed once the problem has been fixed.

Acronyms

This document is incomplete. The external file associated with the glossary 'acronym' (which should be called `template.acr`) hasn't been created.

Check the contents of the file `template.acn`. If it's empty, that means you haven't indexed any of your entries in this glossary (using commands like `\gls` or `\glsadd`) so this list can't be generated. If the file isn't empty, the document build process hasn't been completed.

You may need to rerun LaTeX. If you already have, it may be that TeX's shell escape doesn't allow you to run makeindex. Check the transcript file `template.log`. If the shell escape is disabled, try one of the following:

- Run the external (Lua) application:

  ```
  makeglossaries-lite "template"
  ```

- Run the external (Perl) application:

  ```
  makeglossaries "template"
  ```

Then rerun LaTeX on this document.
This message will be removed once the problem has been fixed.

Symbols

This document is incomplete. The external file associated with the glossary 'symbols' (which should be called `template.sls`) hasn't been created.

Check the contents of the file `template.slo`. If it's empty, that means you haven't indexed any of your entries in this glossary (using commands like `\gls` or `\glsadd`) so this list can't be generated. If the file isn't empty, the document build process hasn't been completed.

You may need to rerun LaTeX. If you already have, it may be that TeX's shell escape doesn't allow you to run makeindex. Check the transcript file `template.log`. If the shell escape is disabled, try one of the following:

- Run the external (Lua) application:

  ```
  makeglossaries-lite "template"
  ```

- Run the external (Perl) application:

  ```
  makeglossaries "template"
  ```

Then rerun LaTeX on this document.

This message will be removed once the problem has been fixed.

1

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[24], 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[35, 9]. 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[27] disrupted services from banking to smart homes worldwide, demonstrating how a DNS configuration error in a *single region* can cascade into global disruptions[25].

Attempts have been made to address these challenges through incremental improvements, such as shifting focus to edge computing in order to reduce latency[9, 35, 21], redundant cloud regions for availability[17, 16], and hybrid architectures that combine local and remote processing[1, 6, 12].

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.

fazer distinção maior entre iot e domotics?

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[21, 19], reduced

availability during network disruptions or cloud outages[33, 16], 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 [8] 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.

fico na dúvida se devia reword this para não "prometer too much"?

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.

2

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:

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.

mencionar MQTT, CoAP em detalhe somewhere

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 [14] 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 [20], 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) [31] 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

7

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 [11] 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.

encontrar outro paper para inserir aqui

2.1.3 Runtime Adaptive Protocol Selection

A recent approach to protocol adaptation is presented in [36], 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.

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.

Nevertheless, the evaluation methodology provides valuable insight into the energy expenditure of these different approaches (further explored in Section 2.4.2), 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 [28] 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

While existing multi-channel approaches rely on centralized decision-making for channel selection – whether through master nodes (MCSC-WoT), SDN controllers (MINOS), or in-frastructure endpoints – **MicroBabel** will address these limitations through decentralized *protocol* selection, extending beyond single-medium channel hopping.

The system will employ 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. This selection will be performed through local decision-making informed by information gathered through gossip protocols, without requiring SDN controllers or infrastructure coordination.

> nail down a arquitetura primeiro maybe

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.

> again discutir arquitetura

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.

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 [11] 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 [13], in which each node maintains two distinct partial views for scalability: a small active view (size = 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 [30].

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 [22] 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 [18] 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-enabled 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.

queremos mingle com o Babel... se calhar não entrar por aqui ou tudo bem porque não vamos usar os big-babeis para coordination?

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

Tree topologies and coordinator-based approaches limit resilience, and heavyweight middleware platforms or HyParView's TCP requirements exceed embedded device capabilities.

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.

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

Multi-channel communication strategies, particularly those that employ coordinated channel hopping for security or efficiency reasons, require nodes to maintain synchronized clocks. Without time synchronization, devices cannot agree on when to switch channels, rendering coordinated multi-protocol operation impossible.

Traditional master-based synchronization approaches – where a designated coordinator is responsible for communicating timing signals – once more fall into the trap of having a single point of failure in that same master node: should it fail, the entire network becomes susceptible to losing accurate temporal reference, leading to the collapse of any coordination efforts.

This is a notorious challenge to overcome when designing distributed systems, and it becomes more prominent in the disaster scenarios discussed thus far, where infrastructure failures are likely to eliminate the nodes responsible for time synchronization in a given system.

Achieving robust time synchronization in such situations requires fully decentralized approaches that eliminate central coordinator dependencies while still remaining sufficiently lightweight to be executed on resource-constrained platforms.

2.3.1 Master-Based Synchronization as Counterexample

As discussed in Section 2.1.1, the MCSC-WoT framework [3] demonstrates a security-focused multi-channel hopping approach aimed at embedded platforms, but with a fundamental dependency on a master node broadcasting synchronization signals.

This approach uses a shared PRNG seed to generate channel-hopping sequences, with the master node broadcasting periodic synchronization beacons that slave nodes use to compensate for clock drift. Nodes that lose synchronization altogether can rejoin by hopping to a random channel and waiting for the next master beacon.

While the proposed goals were achieved in terms of minimizing energy expenditure and maintaining FHSS patterns, it inherits the fundamental limitation of all master-based approaches mentioned at the start of Section 2.3. If the master fails or becomes unreachable, participating nodes gradually drift out of synchronization until coordinated channel hopping is no longer possible.

The system's clock drift compensation algorithm demonstrates the feasibility of synchronization on ESP32 platforms, and their measured AES encryption performance validates that lightweight security can coexist with time synchronization on resource-constrained devices. However, the architectural dependency on a central coordinator fundamentally conflicts with infrastructure-independent operation requirements we aim to fulfill.

2.3.2 Gossip-Based Masterless Synchronization

Decentralized time synchronization eliminates coordinator dependencies by having nodes reach consensus on clock values through distributed local interactions. Two complementary approaches demonstrate the viability of gossip-based synchronization for wireless sensor networks.

mau usar WSN aqui?

The randomized gossip-consensus-based sync (RGCS) algorithm proposed in [34] addresses time synchronization in dynamic WSNs through randomized asynchronous gossip. Each node maintains a logical clock (T) composed of rate (α) and offset (β) parameters, which together transform the node's hardware clock (τ) into synchronized logical time.

Rather than requiring fixed communication links between specific node pairs which might be fragile in dynamic topologies, their approach uses Poisson-based randomized link activation where each potential synchronization link activates with intensity λ.

The synchronization process operates through pairwise gossip exchanges: when a link activates, the triggering node sends a Sync-L beacon selecting a triggered neighbor, followed by bidirectional exchange of multivariable messages containing each node's current logical clock parameters [α, β, τ].

The asynchronous randomized timing of these exchanges is advantageous in that collision rates drop to near zero compared to 19-23% for deterministic communication

protocols, as independent Poisson intervals make simultaneous transmissions to the same receiver statistically unlikely.

The proposed RGCS employs a converge-to-max criterion rather than average-value consensus. This maximum-based approach achieves finite time convergence significantly faster than average-based protocols that require many iterations to converge under significant clock drift. Offset compensation follows suit, with nodes adjusting β parameters based on the difference between their and the neighbors' logical clocks.

Bounded communication delays are handled through a least-square estimation low-pass filter. This addresses the realistic concern of uplink and downlink delays differing, and avoids the symmetric delay assumptions made by many theoretical protocols. The filter's weighing parameter decreases over time, in order to restrain the negative effects of additive noise in stochastic approximation.

Storage complexity remains $O(|N_i|)$ per node per iteration (proportional only to the number of neighbors, not network size) thus ensuring scalability. The protocol simultaneously compensates both clock rate and offset, unlike approaches that handle these separately and thus require additional convergence time.

2.3.3 Coordination Through Passive View Maintenance

As discussed in Section 2.2.1, the shuffle-based passive view maintenance presented in HyParView [13] provides a complementary coordination mechanism. While primarily designed for topology management, the periodic shuffle operations in which nodes exchange lists of known peers can also serve the purpose of propagating network membership information that can inform synchronization decisions.

Nodes performing shuffle exchanges already communicate periodically; these same communication windows can opportunistically carry synchronization messages, reducing protocol overhead. The passive view serves as a pool of potential sync partners, so that when a node's active sync neighbors become unreachable, it can initiate sync exchanges with passive view members, providing added resilience to topology changes without requiring global network knowledge.

2.3.4 MicroBabel's Approach

While MCSC-WoT demonstrates master-based synchronization feasibility and RGCS provides masterless convergence, both assume homogeneous single-protocol networks.

MicroBabel will extend RGCS to heterogeneous multi-protocol networks through protocol-specific Poisson processes with distinct activation rates. Rather than a single λ controlling overall sync frequency, the system employs per-protocol gossip rates that take into account the energy required for each transmission, and the current network conditions:

λ_**BLE** (high frequency): provides rapid local synchronization with nearby neighbors, leveraging BLE's low energy cost for frequent exchanges

λ_**LoRa** (low frequency): maintains long-range temporal coordination, using LoRa's more expensive transmissions sparingly

λ_**Wi-Fi** / Others (medium frequency): situational use based on network density, energy budgets and other factors

Each protocol will have its own Poisson-triggered gossip loop, but all updates contribute to a single shared logical clock via the converge-to-max criterion explored above. When sync events from different protocols occur near-simultaneously, the max operation's associativity ensures correct convergence regardless of update order.

This multi-graph gossip approach provides several advantages over homogeneous sync:

Faster convergence: High-frequency BLE gossip can achieve tighter local consensus while sparse LoRa exchanges prevent drift between distant clusters. The combination converges faster than either protocol alone.

Resilience through diversity: If 2.4 GHz interference disrupts BLE/Wi-Fi synchronization, LoRa maintains loose temporal coordination across the network. Conversely, if LoRa experiences poor conditions, local BLE sync keeps nearby nodes coordinated.

Natural energy optimization: Protocol characteristics directly inform sync frequencies, so that more expensive long-range transmissions occur rarely while cheap short-range exchanges happen frequently, matching energy budgets to communication needs.

Hysteresis control mechanisms adapted from Section 2.1 will prevent oscillations in protocol selection during sync events: sync partner and protocol choices stabilize around locally optimal configurations rather than continuously switching between equally-viable options.

The approach aims to handle network partitions gracefully: nodes maintain synchronization within their reachable partition using available protocols, and when partitions merge (through mobility or topology changes), the converge-to-max criterion naturally reconciles previously independent temporal references without requiring special merge logic.

Unlike MCSC-WoT's master-based approach, this architecture will operate in a fully peer-to-peer fashion with no fixed coordinator dependencies. The multi-protocol extension goes beyond RGCS's original homogeneous network assumptions, since heterogeneous gossip graphs with protocol-specific characteristics warrant distinct sync frequencies, enabling simultaneous optimization of convergence speed, energy consumption, and range coverage.

2.4 Lightweight Data Compression and Energy Efficiency

Energy constraints present one of the most fundamental limitations in battery-powered IoT deployments, particularly in hazardous deployments where replacements and recharging are impractical, and during disaster scenarios where grid power likely becomes unavailable.

While multi-protocol communication and decentralized coordination efforts provide resilience, they also introduce increaed energy costs through frequent transmissions, protocol adaptation overhead and forwarding costs.

Data transmission dominates energy consumption across wireless technologies: LoRa and SIGFOX can represent up to 99.9% of power consumption for transmission, while even shorter-range technologies like BLE and IEEE 802.15.4 dedicate 85-90% of their energy budget to radio operations [26]. This reality makes data reduction techniques essential for extending operational lifetime in infrastructure-independent scenarios.

2.4.1 Prediction-Based Data Reduction

The Ambrosia protocol [26] demonstrates that lightweight prediction can achieve substantial data reductions on resource-constrained devices. The core idea is that not all sensor readings need to be transmitted if their values can be accurately predicted at the server (within the bounds of a specified error threshold), provided that both sender and receiver maintain a synchronized "prediction state".

Their approach uses window-based forecasting where the next sample is predicted by adding the average differences between recent previous samples, making it dramatically lighter than sophisticated time-series forecasting techniques like ARIMA [23] while still achieving comparable data reduction performance.

The protocol works by sending the first w (window size) true samples collected by the sensor node to the server, and for every sample after that comparing its true value to the one predicted locally; the true sample value is sent to the server only if the absolute difference between it and the prediction is greater than a user or application-specified error threshold δ.

The same simple prediction scheme is used on both ends of this communication, and the predicted value is the one used for further predictions – even on the sensor node that knows the true value, to ensure consistency between the two endpoints.

This design achieves up to 60% data reduction with appropriate δ configuration while maintaining sufficient accuracy for diverse applications: for error-tolerant use cases like anomaly detection, δ values will be higher to allow for reasonable fluctuations, thus enabling more significant data reductions, while error-sensitive applications requiring higher precision will naturally lean towards stricter error thresholds, but still benefitting from some amount of data reduction.

The major takeaway from this work is that the window-based prediction executed 99%

17

faster than ARIMA forecasting in their evaluation, making it viable for streaming sensor data at high rates. The approach achieved 2× battery lifetime improvement in high-traffic scenarios and demonstrated compatibility with extremely constrained devices (livestock ear tags with Atmel 8-bit microcontrollers).

2.4.2 Receiver-Side Energy Considerations

An oft-overlooked aspect of IoT energy optimization is the asymmetry between sender and receiver energy consumption. The adaptive protocol selection framework analysis [36] revealed that receiver nodes consistently consume 15-20% more energy than senders across all evaluated protocols (MQTT, CoAP, HTTP).

This asymmetry shifts the energy bottleneck from endpoint sensors to intermediary nodes like gateways and has direct implications for gateway power management in disaster scenarios where battery replacement becomes impossible. The increased receiver cost stems from the added computational work required for parsing, processing, and managing incoming messages, particularly at high message rates.

For **MicroBabel**'s proposed two-tier architecture where sensor nodes might eventually forward data to aggregators/gateways, this finding has direct implications in that managing the power consumption of these gateways becomes as significant as sensor power optimization, since one gateway might receive substantial data from several nodes even if individually they don't perform frequent transmissions.

2.4.3 MicroBabel's Approach

Extending Ambrosia's lightweight prediction approach to multi-protocol scenarios, **MicroBabel** will reduce data transmission through prediction-based filtering: nodes transmit sensor readings only when prediction error exceeds configurable thresholds (similar to Ambrosia), with protocol-aware tuning to balance accuracy against energy constraints across heterogeneous protocols.

Adaptive threshold selection will adjust δ based on both channel characteristics and node state:

- **High δ for LoRa**: Tolerates larger prediction errors to minimize expensive long-range transmissions, sending only when predictions deviate significantly

- **Low δ for BLE**: Requires tighter prediction accuracy for cheap local exchanges, allowing for more frequent transmissions to maintain precision

- **Battery-aware adaptation**: As node energy depletes, increased δ across all channels reduces transmission frequency, extending lifetime for critical messages

Application-aware transmission will distinguish between data types: periodic sensor readings (temperature, humidity, light) use window-based prediction with configurable δ thresholds, while discrete events (emergency alerts, button presses, motion detection)

transmit immediately without prediction. For predictable streams, accuracy-critical applications maintain low δ, while trend monitoring can accept higher values to reduce transmission frequency.

Gateway energy management accounts for the 15-20% receiver energy cost by implementing selective radio shutdown: gateways can disable specific protocols during low-activity periods, waking periodically to check for incoming sync beacons or when prompted via other protocols.

The expectation is that the combination of lightweight prediction, adaptive thresholding, and protocol-specific tuning will provide substantial energy savings without requiring complex and computationally intensive compression algorithms that would themselves consume significant power.

> entrar pela coisa de desligar os rádios ainda mais?

> inserir algo sobre ACTUAL compression

2.5 Security and Privacy for Resource-Constrained Emergency Communication

Disaster scenarios inherently involve sensitive data, such as location tracking for search-and-rescue operations, environmental conditions for risk assessment, among many others.

Unlike conventional IoT deployments where security infrastructure can be carefully provisioned, emergency-focused deployments must balance security guarantees against the possibility of infrastructure failure.

Traditional security approaches that assume persistent connectivity to Certificate Authorities (CAs), Key Distribution Centers (KDCs), or even blockchain networks cannot fully function, if at all, when those very structures collapse. Embedded platforms further exacerbate this issue by ruling out computationally expensive cryptographic approaches that could more easily provide a given network with a certain degree of independence from those structures.

2.5.1 Lightweight Encryption on Embedded Platforms

The MCSC-WoT framework [3] demonstrates that AES encryption can operate efficiently on ESP32 platforms while maintaining multi-channel communication. Their implementation combines AES encryption with dynamic channel hopping, using a PRNG-based sequence to coordinate channel switches across devices.

The measured encryption overhead validates that symmetric cryptography remains viable on resource-constrained devices, though their approach assumes a shared PRNG seed can be distributed during an initial deployment phase.

While suitable for scenarios where controlled deployment precedes operation, the seed distribution mechanism can become problematic for nodes joining dynamically during emergency scenarios. The master-based synchronization also reintroduces coordinator dependencies that conflict with infrastructure-independent operation requirements, as previously noted.

> queremos fazer algo no angulo de deployments DURING emergencies ou focar apenas na sequencia deployment normal -> emergency operation?

2.5.2 Distributed Key Management

The challenge of establishing shared cryptographic keys across resource- constrained devices without central coordination has received substantial attention, though most approaches make assumptions incompatible with disaster scenarios.

Polynomial-Based Key Management

The LPKM (Lightweight Polynomial-based Key Management) protocol [7] provides a compelling foundation for embedded key distribution. Using polynomial evaluation on 8MHz ATmega128L microcontrollers, this approach generates 128-bit group keys in 2-16 milliseconds with storage requirements of only 496-1616 bytes (depending on security parameter k).

The proposed scheme supports multiple key types within a unified framework: pairwise keys between (non-)neighboring nodes, cluster keys for local groups, and group keys for larger networks. Storage complexity is $O(k + 1)$ coefficients per node, independent of network or group size, ensuring scalability.

No less critical for disaster scenarios – where the possibility of malicious agents must still be taken into account – LPKM enables distributed revocation without central coordination. When a node is compromised, legitimate nodes can independently compute updated keys that exclude the revoked member, with no re-keying delay or coordinator involvement. Periodic share updating provides backward secrecy through timer-based refresh operations that require no coordination.

This approach does assume secure bootstrapping via a KDC that preloads polynomial shares into devices before deployment. For planned disaster-resilience installations (**TODO: campus thing?**), this physical preloading is acceptable. For rapid deployment during emergencies, a trusted device (laptop, PDA, etc.) can serve as a temporary KDC to provision newly added nodes.

Zero-Preloading Approaches

Alternative schemes attempt to eliminate pre-distributed keys entirely. The lightweight distributed key agreement protocol presented in [15] achieves a considerable speedup compared to Diffie-Hellman by employing hash functions and bit-wise comparisons rather than modular exponentiation.

The approach generates temporal key pairs on-demand through random secret number generation, with nodes deriving shared keys via hash-based operations and bit-wise comparisons of prefix bit-strings, thus eliminating the need for pre-distributed keys.

However, it requires an inter-sensor authentication protocol to secure the initial public key exchange, creating a circular dependency: authentication requires keys, but key establishment requires authentication. Furthermore, revocation mechanisms are only briefly mentioned without any concrete details, limiting the potential of this implementation.

This highlights a fundamental pressure point in zero-config security: establishing trust without pre-shared secrets or trusted third parties.

2.5.3   Centralized Security Approaches (Incompatible with Disasters)

Several recent approaches leverage blockchain or centralized infrastructure to solve IoT security challenges, but their dependencies render them unsuitable for disaster scenarios.

The blockchain-based access control system in [29] moves Policy Decision Points onto distributed ledgers, eliminating single points of failure in access control. However, it assumes continuous connectivity to blockchain nodes and cloud storage for off-chain data, failing precisely when infrastructure collapses.

Similarly, the decentralized PKI approach using blockchain-based Name/Value Storage [32] replaces Certificate Authorities with distributed blockchain nodes. While removing central CA dependencies, it still requires Internet connectivity for NVS queries and assumes blockchain nodes remain reachable, which invalidates their usage during disasters.

Decentralized attribute-based encryption (ABE) schemes [10] eliminate central authorities through multi-authority cryptography but rely on bilinear pairings with computational costs far exceeding the capabilities of our targeted platforms.

2.5.4   MicroBabel's Approach

LPKM provides lightweight key management but requires initial KDC provisioning, while zero-config approaches face circular authentication dependencies and centralized schemes fail when infrastructure collapses.

MicroBabel will adopt a hybrid security model that distinguishes between pre-disaster deployment and post-disaster autonomous operation.

Pre-disaster deployment phase: For planned installations (building sensor networks, campus-wide monitoring), polynomial shares will be preloaded via KDC during initial deployment, whereas for rapid emergency deployment, a trusted device will serve as a temporary KDC to distribute shares to newly added nodes.

again, queremos lean into mid-disaster deployment?

These are reasonable assumptions for disaster-resilience scenarios, as preparation happens before any emergency operation needs to take place.

Post-disaster autonomous operation: Once a disaster occurs and infrastructure fails, the network operates autonomously using mechanisms that require no central coordination:

   - **Distributed revocation** (adapted from LPKM): nodes independently compute updated keys excluding compromised peers, with revocation decisions propagated via gossip

21

- **Periodic share updating** (adapted from LPKM): timer-based key refresh for backward secrecy, no coordinator needed

- **Lightweight encryption**: AES encryption (demonstrated by MCSC-WoT on ESP32) with compress-then-encrypt strategies 2.4 to minimize ciphertext size and transmission energy

- **Channel hopping/protocol switching for security**: multi-channel/multi-protocol operation complicates eavesdropping and uses masterless synchronization (RGCS) rather than master-based beacons

Threat model: The system will prioritize availability and resilience over complete compromise resistance. Assumptions include:

- **Honest majority**: most nodes behave correctly; adversaries cannot compromise majority simultaneously

- **Local adversary**: attackers can monitor/disrupt local regions but not entire network simultaneously

- **Physical security during deployment**: devices can be provisioned securely before disaster strikes

This threat model reflects emergency priorities where maintaining communication capability matters more than preventing all possible attacks. If an adversary with sophisticated capabilities attacks during a disaster, communication infrastructure would already be their target regardless of security mechanisms.

3

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 al-ternative 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.
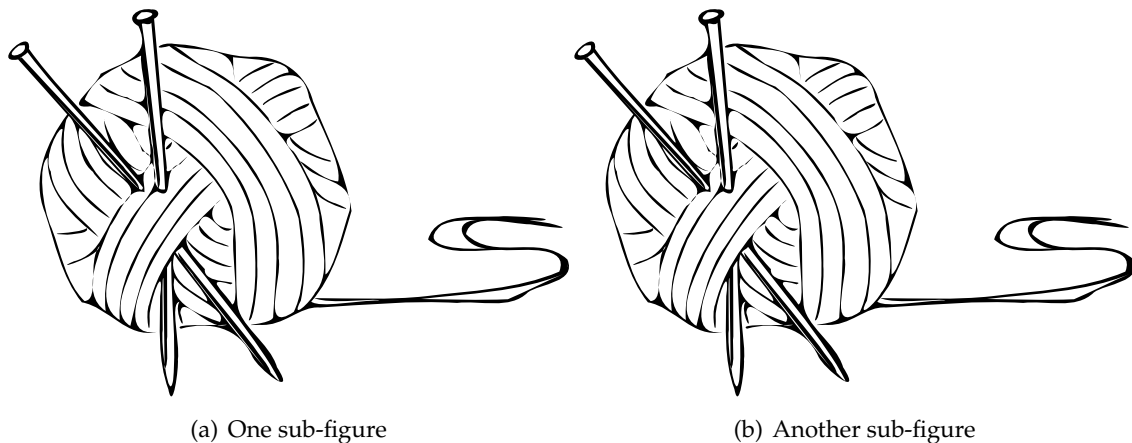
3.6   Text Formatting

3.7   Generating PDFs from LaTeX

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 LaTeX. 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 úinico \cite{...}.

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

3.7.4 Footnotes

Footnotes[1] 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 [**Artho0**]	1	4	1	*2B, 1C*	0
Local Variable [**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

---

[1]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)
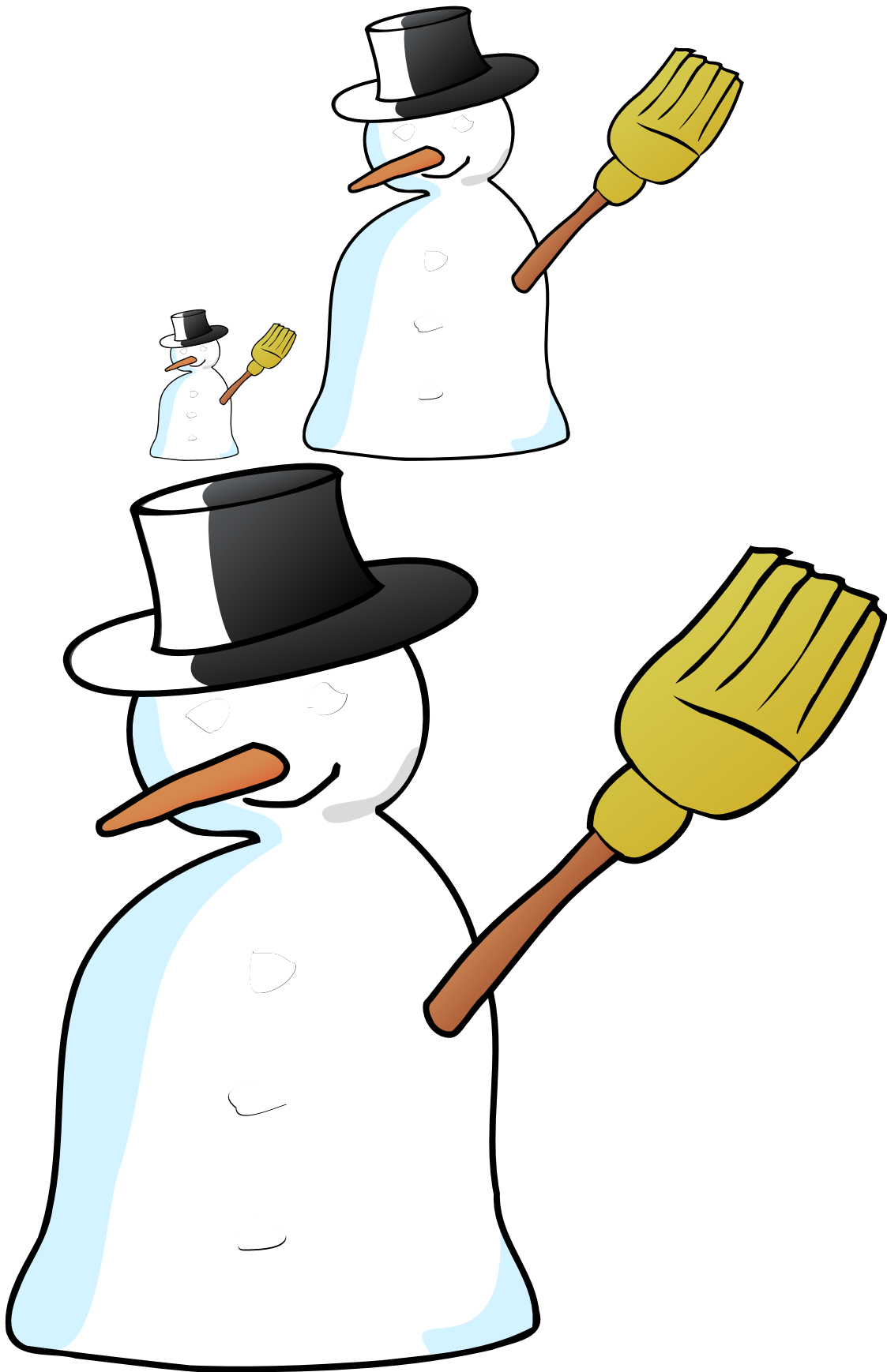
Figure 3.3: Vectorial image (PDF)
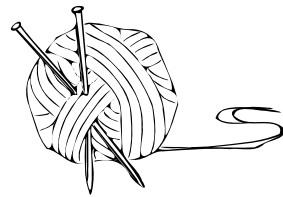
(a) Novelo de lã

(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.ldf`, 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 is 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.

Bibliography

[1]   S. M. Alamouti, F. Arjomandi, and M. Burger. "Hybrid Edge Cloud: A Pragmatic Approach for Decentralized Cloud Computing". In: *IEEE Communications Magazine* 60.9 (2022), pp. 16–29. DOI: 10.1109/MCOM.001.2200251 (cit. on p. 1).

[2]   Z. Amiri et al. "Resilient and dependability management in distributed environments: A systematic and comprehensive literature review". In: *Cluster Computing* 26.2 (2023), pp. 1565–1600 (cit. on p. 3).

[3]   P. Barman, R. Chowdhury, and B. Saha. "Multi-channel secure communication framework for wireless IoT (MCSC-WoT): enhancing security in Internet of Things". In: *Cluster Computing* 28.11 (2025), p. 691 (cit. on pp. 7, 14, 19).

[4]   R. Casadei et al. "Engineering Resilient Collaborative Edge-Enabled IoT". In: *2019 IEEE International Conference on Services Computing (SCC)*. 2019, pp. 36–45. DOI: 10.1109/SCC.2019.00019 (cit. on p. 12).

[5]   M. Chui, M. Collins, and M. Patel. *The Internet of Things: Catching up to an accelerating opportunity*. McKinsey & Company. 2021-11. URL: https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/iot-value-set-to-accelerate-through-2030-where-and-how-to-capture-it (visited on 2025-12-26) (cit. on p. 1).

[6]   A. Dauda, O. Flauzac, and F. Nolot. "A Survey on IoT Application Architectures". In: *Sensors* 24.16 (2024). ISSN: 1424-8220. DOI: 10.3390/s24165320 (cit. on p. 1).

[7]   X. Fan and G. Gong. "LPKM: A Lightweight Polynomial-Based Key Management Protocol for Distributed Wireless Sensor Networks". In: *Ad Hoc Networks*. Ed. by J. Zheng et al. Berlin, Heidelberg: Springer Berlin Heidelberg, 2013, pp. 180–195. ISBN: 978-3-642-36958-2. DOI: 10.1007/978-3-642-36958-2_13 (cit. on p. 20).

[8]   P. Fouto et al. "Babel: A Framework for Developing Performant and Dependable Distributed Protocols". In: *2022 41st International Symposium on Reliable Distributed Systems (SRDS)*. 2022, pp. 146–155. DOI: 10.1109/SRDS55811.2022.00022 (cit. on p. 3).

[9]   S. Hamdan, M. Ayyash, and S. Almajali. "Edge-Computing Architectures for Internet of Things Applications: A Survey". In: *Sensors* 20.22 (2020). ISSN: 1424-8220. DOI: `10.3390/s20226441` (cit. on p. 1).

[10]   J. Han et al. "Privacy-Preserving Decentralized Key-Policy Attribute-Based Encryption". In: *IEEE Transactions on Parallel and Distributed Systems* 23.11 (2012), pp. 2150–2162. DOI: `10.1109/TPDS.2012.50` (cit. on p. 21).

[11]   K. Khanchuea and R. Siripokarpirom. "A Multi-Protocol IoT Gateway and WiFi/BLE Sensor Nodes for Smart Home and Building Automation: Design and Implementation". In: *2019 10th International Conference of Information and Communication Technology for Embedded Systems (IC-ICTES)*. 2019, pp. 1–6. DOI: `10.1109/ICTEmSys.2019.8695968` (cit. on pp. 8, 10).

[12]   D. Kreković et al. "Reducing communication overhead in the IoT–edge–cloud continuum: A survey on protocols and data reduction strategies". In: *Internet of Things* 31 (2025), p. 101553. ISSN: 2542-6605. DOI: `https://doi.org/10.1016/j.iot.2025.101553` (cit. on p. 1).

[13]   J. Leitao, J. Pereira, and L. Rodrigues. "HyParView: A Membership Protocol for Reliable Gossip-Based Broadcast". In: *37th Annual IEEE/IFIP International Conference on Dependable Systems and Networks (DSN'07)*. 2007, pp. 419–429. DOI: `10.1109/DSN.2007.56` (cit. on pp. 10, 15).

[14]   H. Li, K. Ota, and M. Dong. "Always Connected Things: Building Disaster Resilience IoT Communications". In: *2019 IEEE 25th International Conference on Parallel and Distributed Systems (ICPADS)*. 2019, pp. 570–577. DOI: `10.1109/ICPADS47876.2019.00087` (cit. on p. 7).

[15]   C.-C. Lin, S. Shieh, and J.-C. Lin. "Lightweight, Distributed Key Agreement Protocol for Wireless Sensor Networks". In: *2008 Second International Conference on Secure System Integration and Reliability Improvement*. 2008, pp. 96–102. DOI: `10.1109/SSIRI.2008.30` (cit. on p. 20).

[16]   P. Maciel et al. "A survey on reliability and availability modeling of edge, fog, and cloud computing". In: *Journal of Reliable Intelligent Environments* 8.3 (2022), pp. 227–245 (cit. on pp. 1, 3).

[17]   M. R. Mesbahi, A. M. Rahmani, and M. Hosseinzadeh. "Reliability and high availability in cloud computing environments: a reference roadmap". In: *Human-centric Computing and Information Sciences* 8.1 (2018), p. 20 (cit. on p. 1).

[18]   R. Montella, M. Ruggieri, and S. Kosta. "A fast, secure, reliable, and resilient data transfer framework for pervasive IoT applications". In: *IEEE INFOCOM 2018 - IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)*. 2018, pp. 710–715. DOI: `10.1109/INFCOMW.2018.8406884` (cit. on p. 11).

[19] J. Pan and J. McElhannon. "Future Edge Cloud and Edge Computing for Internet of Things Applications". In: *IEEE Internet of Things Journal* 5.1 (2018), pp. 439–449. DOI: 10.1109/JIOT.2017.2767608 (cit. on p. 2).

[20] J. Porte et al. "Heterogeneous wireless IoT architecture for natural disaster monitorization". In: *EURASIP Journal on Wireless Communications and Networking* 2020.1 (2020), p. 184 (cit. on p. 7).

[21] J. Ren et al. "Collaborative Cloud and Edge Computing for Latency Minimization". In: *IEEE Transactions on Vehicular Technology* 68.5 (2019), pp. 5031–5044. DOI: 10.1109/TVT.2019.2904244 (cit. on pp. 1, 2).

[22] K. Scott and S. Burleigh. *Bundle protocol specification*. RFC 5050. RFC Editor, 2007. URL: https://www.rfc-editor.org/rfc/rfc5050.html (cit. on p. 11).

[23] R. H. Shumway and D. S. Stoffer. "ARIMA Models". In: *Time Series Analysis and Its Applications: With R Examples*. Cham: Springer International Publishing, 2017, pp. 75–163. ISBN: 978-3-319-52452-8. DOI: 10.1007/978-3-319-52452-8_3 (cit. on p. 17).

[24] S. Sinha. "State of IoT 2025: Number of connected IoT devices growing 14% to 21.1 billion globally". In: *IoT Analytics* (2025) (cit. on p. 1).

[25] A. Staff. *Summary of the Amazon DynamoDB Service Disruption in the Northern Virginia (US-EAST-1) Region*. 2025. URL: https://aws.amazon.com/message/101925/ (visited on 2025-12-26) (cit. on p. 1).

[26] S. Suryavansh et al. "A data-driven approach to increasing the lifetime of IoT sensor nodes". In: *Scientific Reports* 11.1 (2021), p. 22459. DOI: 10.1155/2018/4283087 (cit. on p. 17).

[27] I. R. Team. *AWS Outage Analysis: October 20, 2025*. 2025. URL: https://www.thousandeyes.com/blog/aws-outage-analysis-october-20-2025 (visited on 2025-12-26) (cit. on p. 1).

[28] T. Theodorou et al. "A Multi-Protocol Software-Defined Networking Solution for the Internet of Things". In: *IEEE Communications Magazine* 57.10 (2019), pp. 42–48. DOI: 10.1109/MCOM.001.1900056 (cit. on p. 9).

[29] H. T. T. Truong et al. "Towards Secure and Decentralized Sharing of IoT Data". In: *2019 IEEE International Conference on Blockchain (Blockchain)*. 2019, pp. 176–183. DOI: 10.1109/Blockchain.2019.00031 (cit. on p. 21).

[30] S. Voulgaris, D. Gavidia, and M. Van Steen. "Cyclon: Inexpensive membership management for unstructured p2p overlays". In: *Journal of Network and systems Management* 13.2 (2005), pp. 197–217 (cit. on p. 10).

[31] T. Winter et al. *RPL: IPv6 routing protocol for low-power and lossy networks*. RFC 6550. RFC Editor, 2012. URL: https://www.rfc-editor.org/rfc/rfc6550.html (cit. on p. 7).

[32] J. Won et al. "Decentralized Public Key Infrastructure for Internet-of-Things". In: *MILCOM 2018 - 2018 IEEE Military Communications Conference (MILCOM)*. 2018, pp. 907–913. DOI: 10.1109/MILCOM.2018.8599710 (cit. on p. 21).

[33] L. Xing. "Reliability in Internet of Things: Current Status and Future Perspectives". In: *IEEE Internet of Things Journal* 7.8 (2020), pp. 6704–6721. DOI: 10.1109/JIOT.2020.2993216 (cit. on p. 3).

[34] N. Xiong et al. "Randomized and Efficient Time Synchronization in Dynamic Wireless Sensor Networks: A Gossip-Consensus-Based Approach". In: *Complexity* 2018.1 (2018), p. 4283087. DOI: 10.1155/2018/4283087 (cit. on p. 14).

[35] W. Yu et al. "A Survey on the Edge Computing for the Internet of Things". In: *IEEE Access* 6 (2018), pp. 6900–6919. DOI: 10.1109/ACCESS.2017.2778504 (cit. on p. 1).

[36] D. Żatuchin and M. Azarskov. "An Adaptive Protocol Selection Framework for Energy-Efficient IoT Communication: Dynamic Optimization Through Context-Aware Decision Making". In: *Informatics* 12.4 (2025). ISSN: 2227-9709. DOI: 10.3390/informatics12040125 (cit. on pp. 8, 18).

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.

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.

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 consectetuer.

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.

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, consectetuer at, consectetuer 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, consectetuer 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 consectetuer. 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.

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et, 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 consectetuer odio sem sed wisi.

Sed feugiat. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Ut pellentesque augue sed urna. Vestibulum diam eros, fringilla et, consectetuer eu, nonummy id, sapien. Nullam at lectus. In sagittis ultrices mauris. Curabitur malesuada erat sit amet massa. Fusce blandit. Aliquam erat volutpat. Aliquam euismod. Aenean vel lectus. Nunc imperdiet justo nec dolor.

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 consectetuer tortor sapien facilisis magna. Mauris quis magna varius nulla scelerisque imperdiet. 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.

Aliquam lectus. Vivamus leo. Quisque ornare tellus ullamcorper nulla. Mauris porttitor pharetra tortor. Sed fringilla justo sed mauris. Mauris tellus. Sed non leo. Nullam elementum, magna in cursus sodales, augue est scelerisque sapien, venenatis congue nulla arcu et pede. Ut suscipit enim vel sapien. Donec congue. Maecenas urna mi, suscipit in, placerat ut, vestibulum ut, massa. Fusce ultrices nulla et nisl.

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, imperdiet sed, pellentesque nec, nisl. Vestibulum imperdiet 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, consectetuer 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.

Nulla non mauris vitae wisi posuere convallis. Sed eu nulla nec eros scelerisque pharetra. Nullam varius. Etiam dignissim elementum metus. Vestibulum faucibus, metus sit amet mattis rhoncus, sapien dui laoreet odio, nec ultricies nibh augue a enim. Fusce in ligula. Quisque at magna et nulla commodo consequat. Proin accumsan imperdiet sem. Nunc porta. Donec feugiat mi at justo. Phasellus facilisis ipsum quis ante. In ac elit eget ipsum pharetra faucibus. Maecenas viverra nulla in massa.

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, consectetuer adipiscing elit. Nunc ut metus. Ut metus justo, auctor at, ultrices eu, sagittis ut, purus. Aliquam aliquam.

A.1   A section here

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.

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 consectetuer.

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.

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, consectetuer at, consectetuer 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, consectetuer 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 consectetuer. 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.

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et, 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 consectetuer odio sem sed wisi.

Sed feugiat. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Ut pellentesque augue sed urna. Vestibulum diam eros, fringilla et, consectetuer eu, nonummy id, sapien. Nullam at lectus. In sagittis ultrices mauris. Curabitur malesuada erat sit amet massa. Fusce blandit. Aliquam erat volutpat. Aliquam euismod. Aenean vel lectus. Nunc imperdiet justo nec dolor.

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 consectetuer tortor sapien facilisis magna. Mauris quis magna varius nulla scelerisque imperdiet. 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.

Aliquam lectus. Vivamus leo. Quisque ornare tellus ullamcorper nulla. Mauris porttitor pharetra tortor. Sed fringilla justo sed mauris. Mauris tellus. Sed non leo. Nullam elementum, magna in cursus sodales, augue est scelerisque sapien, venenatis congue nulla arcu et pede. Ut suscipit enim vel sapien. Donec congue. Maecenas urna mi, suscipit in, placerat ut, vestibulum ut, massa. Fusce ultrices nulla et nisl.

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, imperdiet sed, pellentesque nec, nisl. Vestibulum imperdiet 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, consectetuer 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.

Nulla non mauris vitae wisi posuere convallis. Sed eu nulla nec eros scelerisque pharetra. Nullam varius. Etiam dignissim elementum metus. Vestibulum faucibus, metus sit amet mattis rhoncus, sapien dui laoreet odio, nec ultricies nibh augue a enim. Fusce in ligula. Quisque at magna et nulla commodo consequat. Proin accumsan imperdiet sem. Nunc porta. Donec feugiat mi at justo. Phasellus facilisis ipsum quis ante. In ac elit eget ipsum pharetra faucibus. Maecenas viverra nulla in massa.

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, consectetuer 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.

AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

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.

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 consectetuer.

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.

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, consectetuer at, consectetuer 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, consectetuer 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 consectetuer. 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.

BBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBBB
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC

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.

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 consectetuer.

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.

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, consectetuer at, consectetuer 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, consectetuer 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 consectetuer. 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.

Suspendisse vitae elit. Aliquam arcu neque, ornare in, ullamcorper quis, commodo eu, libero. Fusce sagittis erat at erat tristique mollis. Maecenas sapien libero, molestie et,

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 consectetuer odio sem sed wisi.

I

Annex 1 Lorem Ipsum

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.

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 consectetuer.