



# **REDIMadrid:** **Estado presente y plan de futuro**

César Sánchez

**XX Jornadas REDIMadrid**

Madrid, 21 de octubre de 2025

# software



César Sánchez

*Director*

Full Professor en IMDEA-Software, donde lidero un grupo de investigación en:

- Métodos formales
- Lógica computacional, teoría de automátas, juegos y lenguajes formales
- Verificación y síntesis, runtime verification
- Sistemas reactivos



César Sánchez

*Director*

Full Professor en IMDEA-Sof

- Métodos formales
- Lógica computacional, te
- Verificación y síntesis, m
- Sistemas reactivos

César Sánchez

## Temporal Logics for Hyperproperties

Michael R. Clarkson<sup>1</sup>, Bernd Finkbeiner<sup>2</sup>, Masoud Koleini<sup>1</sup>,  
Krisztian K. Micinski<sup>3</sup>, Markus N. Rabe<sup>2</sup>, and César Sánchez<sup>4</sup>

<sup>1</sup> George Washington University, USA

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**Abstract.** Two new logics for verification of hyperproperties are proposed. Hyperproperties characterize security policies, such as noninterference, as a property of sets of computation paths. Standard temporal logics such as LTL, CTL, and CTL\* can refer only to a single path at a time, hence cannot express many hyperproperties of interest. The logics proposed here, HyperLTL and HyperCTL\*, add explicit and simultaneous quantification over multiple paths to LTL and to CTL\*. This kind of quantification enables expression of hyperproperties. A model checking algorithm for the proposed logics is given. For a fragment of HyperLTL, a prototype model checker has been implemented.

### 1 Introduction

*Trace properties*, which developed out of an interest in proving the correctness of programs [32], characterize correct behavior as properties of individual execution traces. Although early verification techniques specialized in proving individual correctness properties of interest, such as mutual exclusion or termination, temporal logics soon emerged as a general, unifying framework for expressing and verifying trace properties. Practical model checking tools [11, 16, 28] based on those logics now enable automated verification of program correctness.

Verification of security is not directly possible with such tools, because some important security policies cannot be characterized as properties of individual execution traces [38]. Rather, they are properties of sets of execution traces, also known as *hyperproperties* [15]. Specialized verification techniques have been developed for particular hyperproperties [5, 27, 41, 43], as well as for *2-safety* properties [52], which are properties of pairs of execution traces. But a unifying program logic for expressing and verifying hyperproperties could enable automated verification of a wide range of security policies.

In this paper, we propose two such logics. Both are based, like hyperproperties, on examining more than one execution trace at a time. Our first logic, *HyperLTL*, generalizes linear-time temporal logic (LTL) [44]. LTL implicitly quantifies over only a single execution trace of a system, but HyperLTL allows explicit quantification over multiple execution traces simultaneously, as well as propositions that stipulate relationships among those traces. For example, HyperLTL can express

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## Temporal Logics for Hyperproperties

Michael R. Clarkson<sup>1</sup>,  
Krisopher K. Micinski<sup>3</sup>

<sup>1</sup> George V

<sup>2</sup> Universit

<sup>3</sup> University o

<sup>4</sup> IMDEA

**Abstract.** Two new logics are proposed. Hyperproperties characterize, as a property of sets, properties such as LTL, CTL, at any time, hence cannot express. Proposed here, HyperLTL allows quantification over multiple quantification. This enables expressive algorithm for the proposed prototype model checker [1].

### 1 Introduction

*Trace properties*, which develop programs [32], characterize correctness properties of interest. Although early verifications of temporal logics soon emerged as a verifying trace properties. These logics now enable automated verification.

Verification of security is not important security policies can be examined more than one execution traces [38]. Rather, it is also known as *hyperproperties* [1] developed for particular hyperproperties [52], which are program logic for expressing an automated verification of a wide range.

In this paper, we propose two: on examining more than one execution traces. It generalizes linear-time temporal logic to allow a single execution trace of a specification over multiple execution traces. It stipulates relationships among the

## LOLA: Runtime Monitoring of Synchronous Systems

Ben D'Angelo \* Sriram Sankaranarayanan \* César Sánchez \* Will Robinson \* Bernd Finkbeiner † Henny B. Sipma \* Sandeep Mehrotra ‡ Zohar Manna \*

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**Abstract**—We present a specification language and algorithms for the online and offline monitoring of synchronous systems including circuits and embedded systems. Such monitoring is useful not only for testing, but also under actual deployment. The specification language is simple and expressive; it can describe both correctness/failure assertions along with interesting statistical measures that are useful for system profiling and coverage analysis. The algorithm for online monitoring of queries in this language follows a partial evaluation strategy: it incrementally constructs output streams from input streams, while maintaining a store of partially evaluated expressions for forward references. We identify a class of specifications, characterized syntactically, for which the algorithm's memory requirement is independent of the length of the input streams. Being able to bound memory requirements is especially important in online monitoring of large input streams. We extend the concepts used in the online algorithm to construct an efficient offline monitoring algorithm for large traces.

We have implemented our algorithm and applied it to two industrial systems, the PCI bus protocol and a memory controller. The results demonstrate that our algorithms are practical and that our specification language is sufficiently expressive to handle specifications of interest to industry.

#### I. INTRODUCTION

Monitoring synchronous programs for safety and liveness properties is an important aspect of ensuring their proper runtime behavior. An offline monitor analyzes traces of a system post-simulation to spot violations of

the specification. Offline monitoring is critical for testing large systems before deployment. An online monitor processes the system trace while it is being generated. Online monitoring is used to detect violations of the specification when the system is in operation so that they can be handled before they translate into observable and cascading failures, and to adaptively optimize system performance.

Runtime monitoring has received growing attention in recent years [1], [2], [3]. While static verification intends to show that every (infinite) run of a system satisfies the specification, runtime monitoring is concerned only with a single (finite) trace. Runtime monitoring can be viewed as an extension of testing with more powerful specification languages.

The offline monitoring problem is known to be easy for purely past or purely future properties. It is well known that for past properties, the online monitoring problem can be solved efficiently using constant space and linear time in the trace size. For future properties, on the other hand, the space requirement generally depends on the length of the trace, which suggests that online monitoring may quickly become intractable in practical applications with traces exceeding  $10^6$  simulation steps.

In this paper, we present a specification language, intended for industrial use. The language can express properties involving both the past and the future. It is a functional stream computation language like LUSTRE [4] and ESTEREL [5], with features that are relevant to our problem at hand. It is parsimonious in its number of operators (expressions are constructed from three basic operators), but the resulting expressiveness surpasses temporal logics and many other existing formalisms

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M. Abadi and S. Kremer (Eds.): POST 2005, LNCS 3575, pp. 1–12, 2005.  
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## Temporal Logics for Hyperproperties

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Kristopher K. Micinski<sup>3</sup>

<sup>1</sup> George V

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<sup>3</sup> University o

<sup>4</sup> IMDEA

**Abstract.** Two new logics are proposed. Hyperproperties characterize, as a property of sets, logics such as LTL, CTL, at any time, hence cannot express what is proposed here. HyperLTL allows quantification over multiple quantification; this enables an algorithm for the proposed prototype model checker.

### 1 Introduction

*Trace properties*, which develop programs [32], characterize correct traces. Although early verifications of correctness properties of interest in temporal logics soon emerged as a verifying trace properties. These logics now enable automated verification.

Verification of security is not important security policies can be examined from execution traces [38]. Rather, it is also known as *hyperproperties* [1] developed for particular hyperproperties [52], which are proper program logic for expressing an automated verification of a wide range of properties.

In this paper, we propose two: on examining more than one execution trace, generalizes linear-time temporal logic to allow a single execution trace of a specification over multiple execution traces to stipulate relationships among the

## LOLA: Runtime

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**Abstract**—We present a specification language for the online and offline monitoring of systems including circuits and embedded systems. Monitoring is useful not only for testing, but also for actual deployment. The specification language is expressive; it can describe both correctness assertions along with interesting statistical assertions useful for system profiling and coverage analysis. The algorithm for online monitoring of a language follows a partial evaluation strategy: it mentally constructs output streams from input while maintaining a store of partially evaluated forward references. We identify a class of assertions characterized syntactically, for which the memory requirement is independent of the input streams. Being able to bound memory is especially important in online monitoring streams. We extend the concepts used in the algorithm to construct an efficient offline monitor for large traces.

We have implemented our algorithm and tested it on two industrial systems, the PCI bus protocol and a controller. The results demonstrate that our approach is practical and that our specification language is expressive enough to handle specifications of interest.

### I. INTRODUCTION

Monitoring synchronous programs for safety properties is an important aspect of a proper runtime behavior. An offline monitor traces of a system post-simulation to spot

This research was supported in part by NSF grants CCR-02-131105, CCR-02-09257, CNS-0411043, by ARO grant DAAD19-01-1-0723, by NIST grant N00014-03-1-0939, by the Siebel Graduate Fellowship, and by the BMBF grant 01 IS C38 B as part of the Versif

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## Boolean Abstractions for Realizability Modulo Theories

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<sup>2</sup> Universidad Politécnica de Madrid, Madrid, Spain

**Abstract.** In this paper, we address the problem of the (reactive) realizability of specifications of theories richer than Boolean, including arithmetic theories. Our approach transforms theory specifications into purely Boolean specifications by (1) substituting theory literals by Boolean variables, and (2) computing an additional Boolean requirement that captures the dependencies between the new variables imposed by the literals. The resulting specification can be passed to existing Boolean off-the-shelf realizability tools, and is realizable if and only if the original specification is realizable. The first contribution is a brute-force version of our method, which requires a number of SMT queries that is doubly exponential in the number of input literals. Then, we present a faster method that exploits a nested encoding of the search for the extra requirement and uses SAT solving for faster traversing the search space and uses SMT queries internally. Another contribution is a prototype in Z3-Python. Finally, we report an empirical evaluation using specifications inspired in real industrial cases. To the best of our knowledge, this is the first method that succeeds in non-Boolean LTL realizability.

### 1 Introduction

Reactive synthesis [30, 31] is the problem of automatically producing a system that is guaranteed to model a given temporal specification, where the Boolean variables (i.e., atomic propositions) are split into variables controlled by the environment and variables controlled by the system. Realizability is the related decision problem of deciding whether such a system exists. These problems have been widely studied [17, 21], especially in the domain of Linear Temporal Logic (LTL) [29]. Realizability corresponds to infinite games where players alternatively choose the valuations of the Boolean variables they control. The winning condition is extracted from the temporal specification and determines which player wins a given play. A system is realizable if and only if the system player

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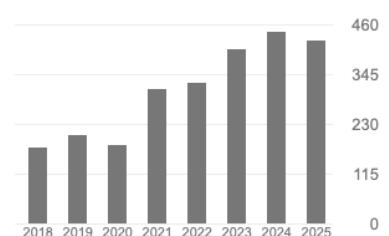
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	Bernd Finkbeiner Professor of Computer Science, ...	>
	Martin Leucker Professor of Computer Science, ...	>

# Equipo de REDIMadrid



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*Director*



David Rincón  
*Coordinador Técnico*



Alejandro Recio  
*Técnico de soporte*



Carlos de Higes  
*Técnico de red*

+ Apoyo de IMDEA-Software:

- gestión y soporte administrativo (María Alcaraz y su equipo, Manuel Carro, Antonio Fernández-Anta)
- técnico (Juan Céspedes, Roberto Lumbreras, Tomás Kriukelis, David Colera)

# Introducción

Jerarquía de **redes telemáticas de investigación:**

- GEANT: Pan-Europea
- RedIRIS: España
- REDIMadrid: Comunidad de Madrid

*Regulado por acuerdo marco*

Sábado 1 junio 2002

BOE núm. 131

MINISTERIO  
DE CIENCIA Y TECNOLOGÍA

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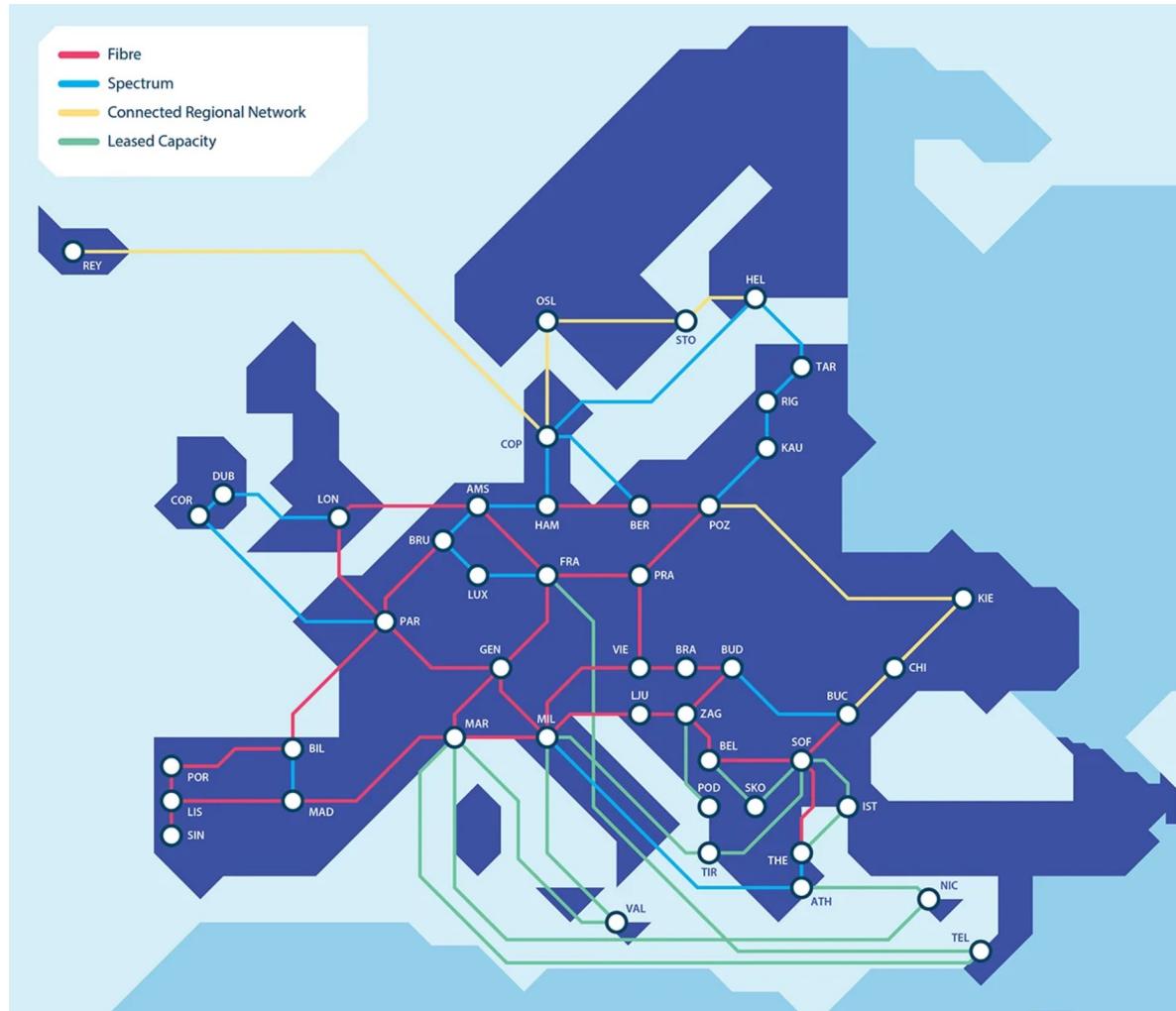
RESOLUCIÓN de 6 de mayo de 2002, de la Secretaría de Estado de Política Científica y Tecnológica, por la que se dispone la publicación del Protocolo General por el que se establece el Acuerdo Marco entre el Ministerio de Ciencia y Tecnología y la Comunidad Autónoma de Madrid para la coordinación de actuaciones en materia de investigación científica, desarrollo e innovación tecnológica.

maurio, 6 de mayo de 2002.—El Secretario de Estado, Ramón Marimon Suñol.

ANEXO

Protocolo General por el que se establece el Acuerdo Marco entre el Ministerio de Ciencia y Tecnología y la Comunidad Autónoma de Madrid para la coordinación de actuaciones en materia de investigación científica, desarrollo e innovación tecnológica

# Geant (Red Europea)



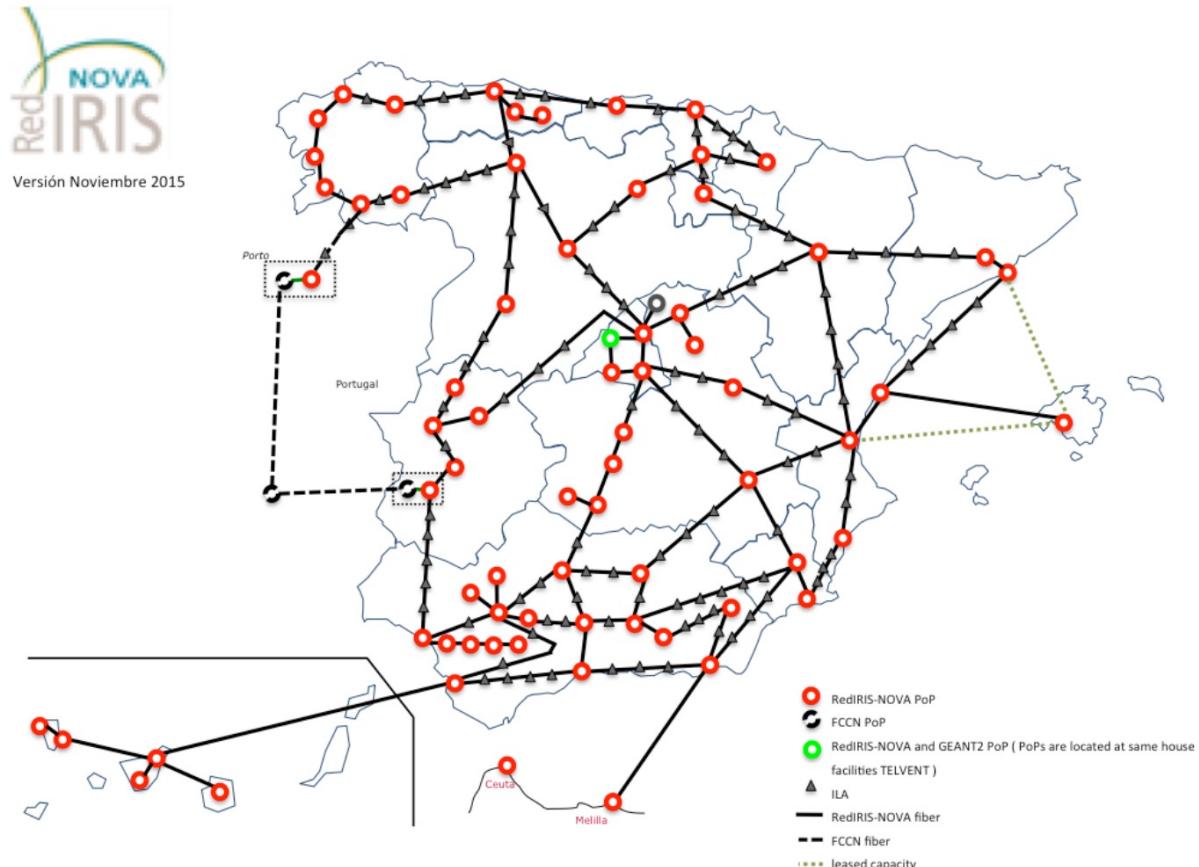
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César Sánchez

21 de octubre

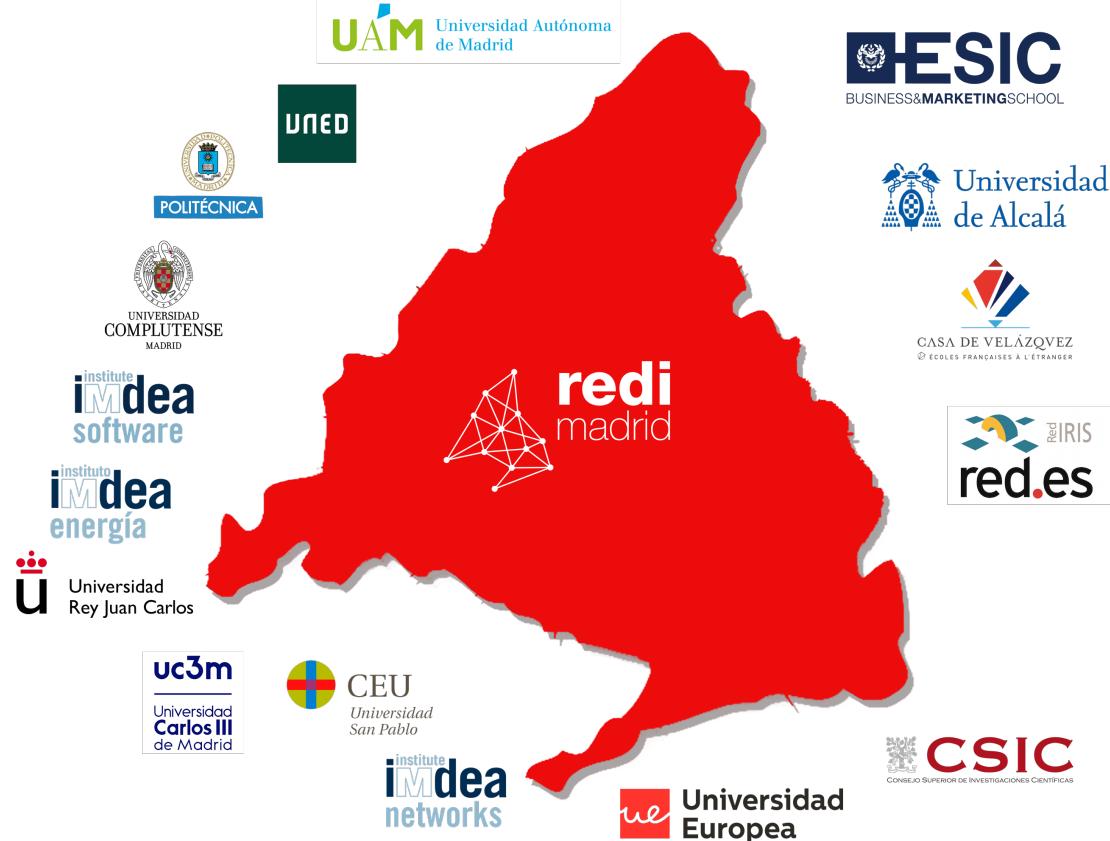
# RedIRIS (Red Española)

Huella de fibra de RedIRIS-NOVA





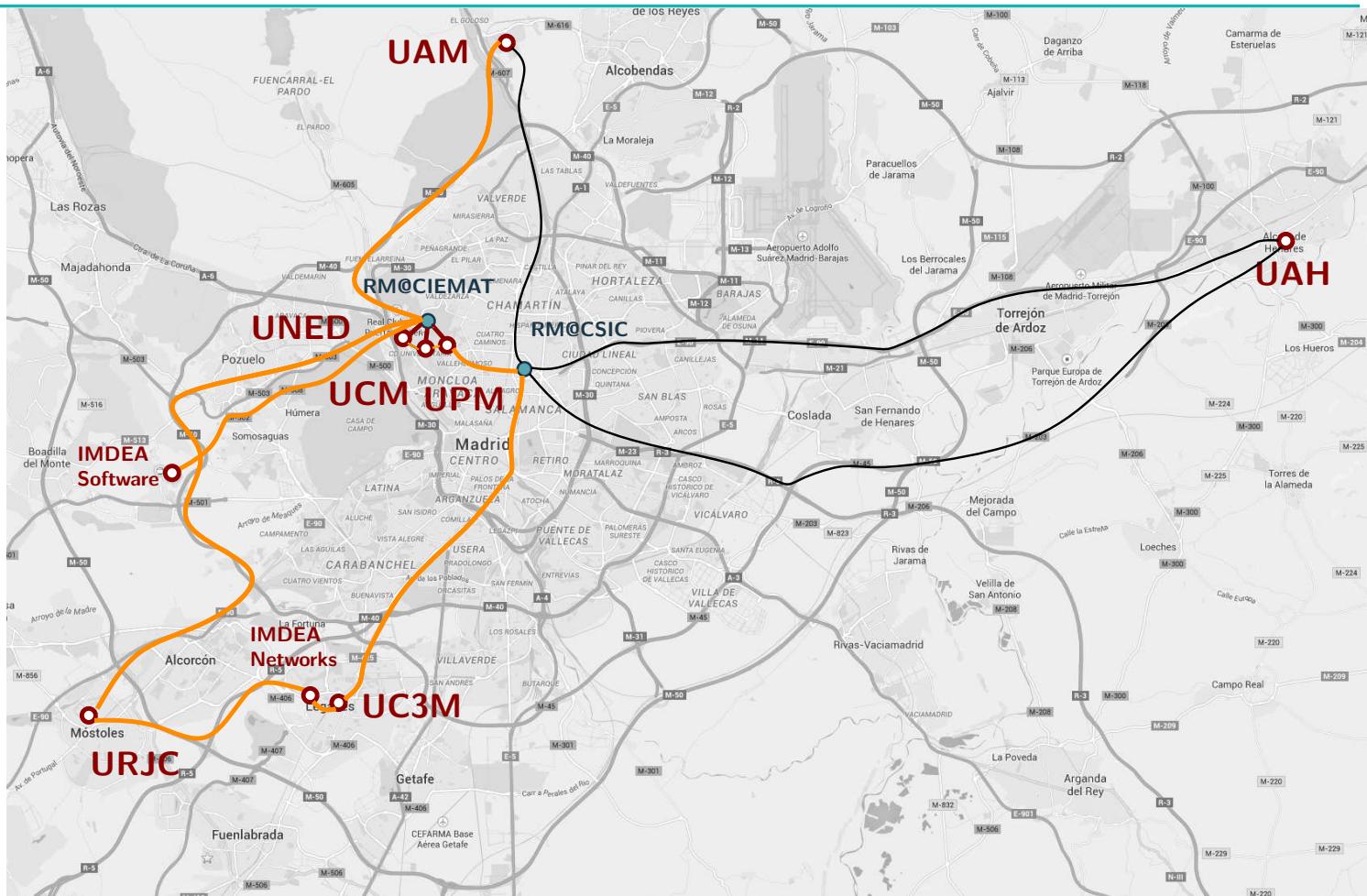
# REDIMadrid (la Red de Madrid)



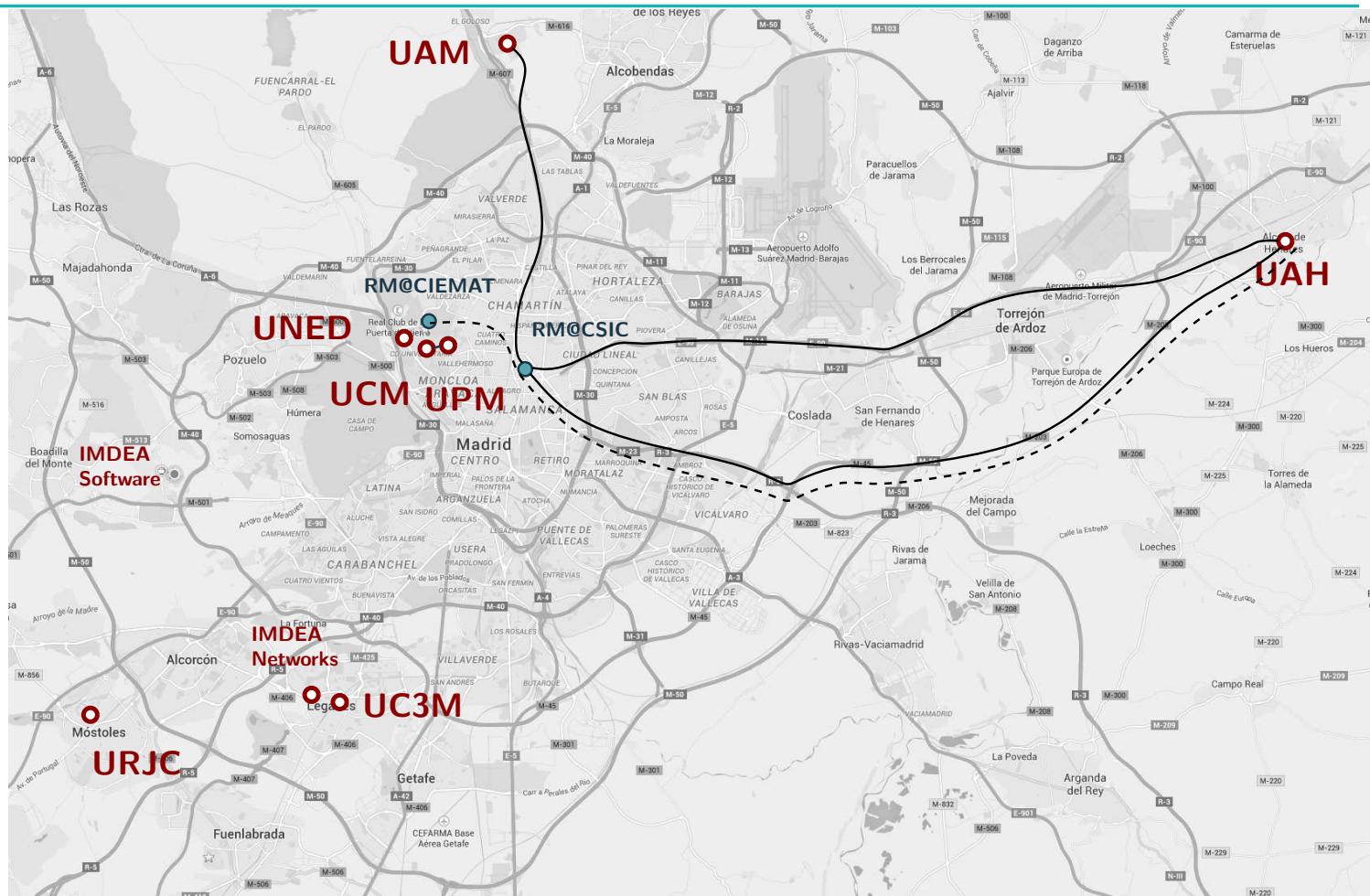
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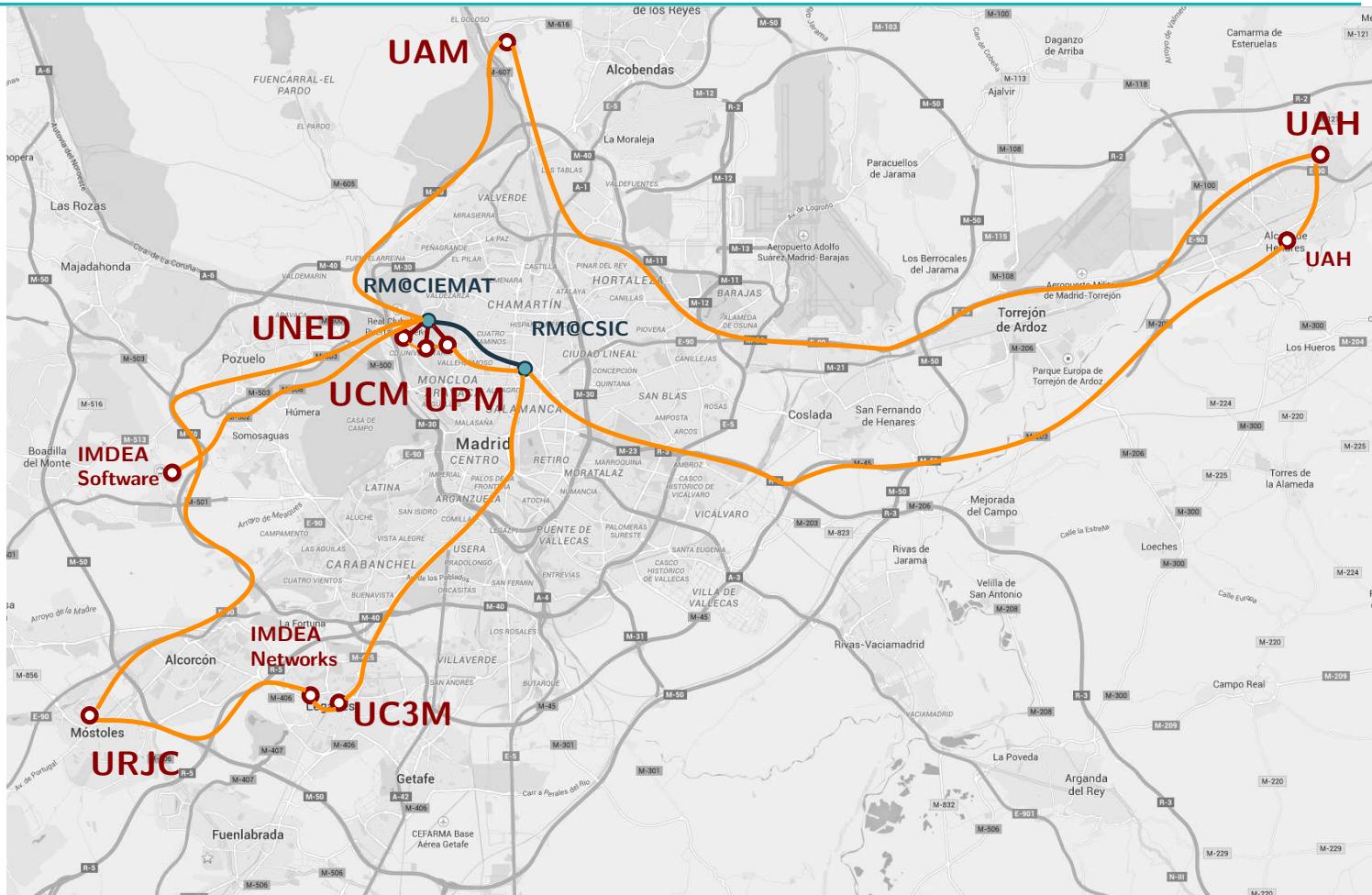
# Topología Física Actual CORE (fin 2025)



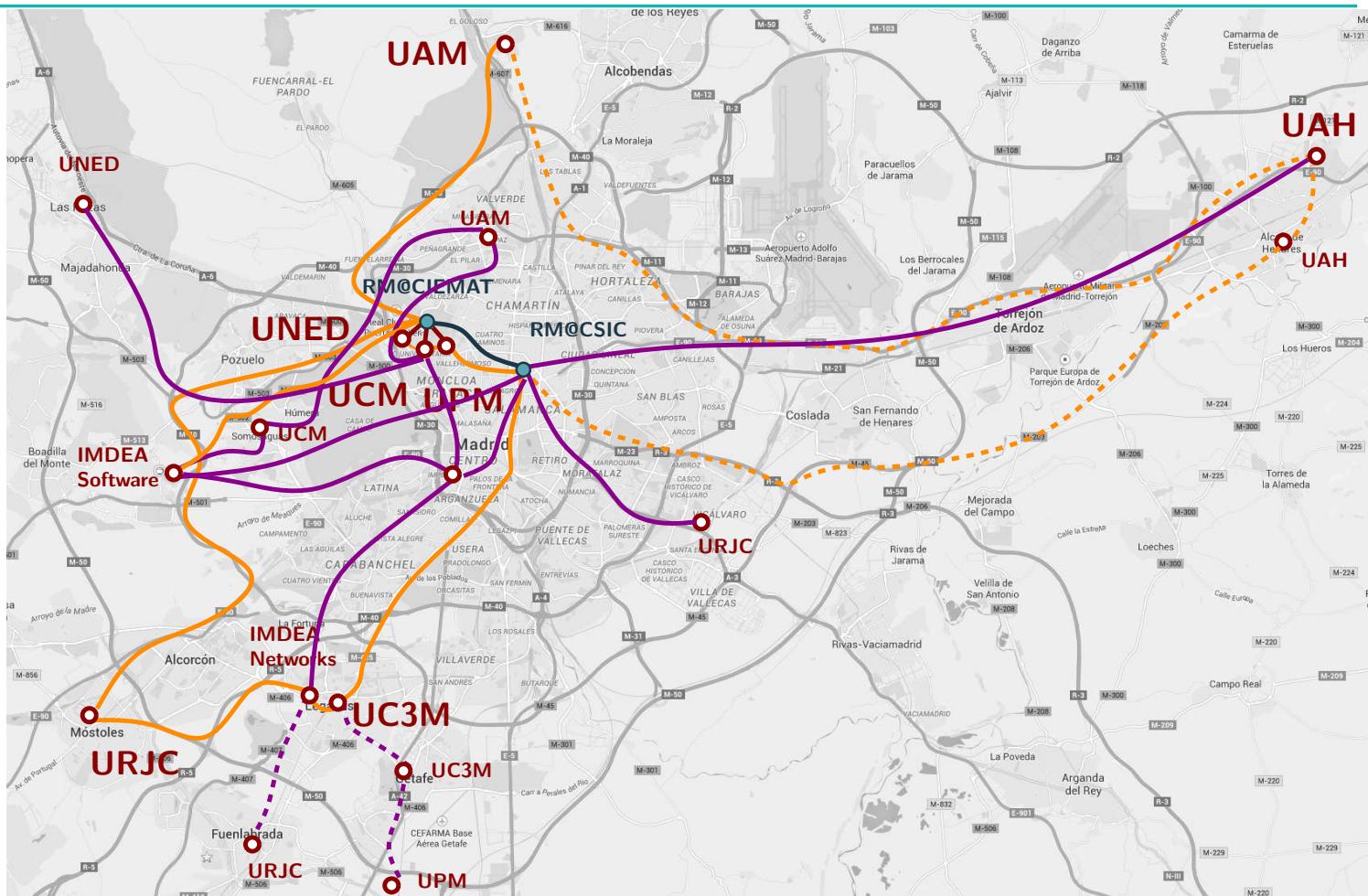
# Topología Anillos Alquiler Remanente (2025-)



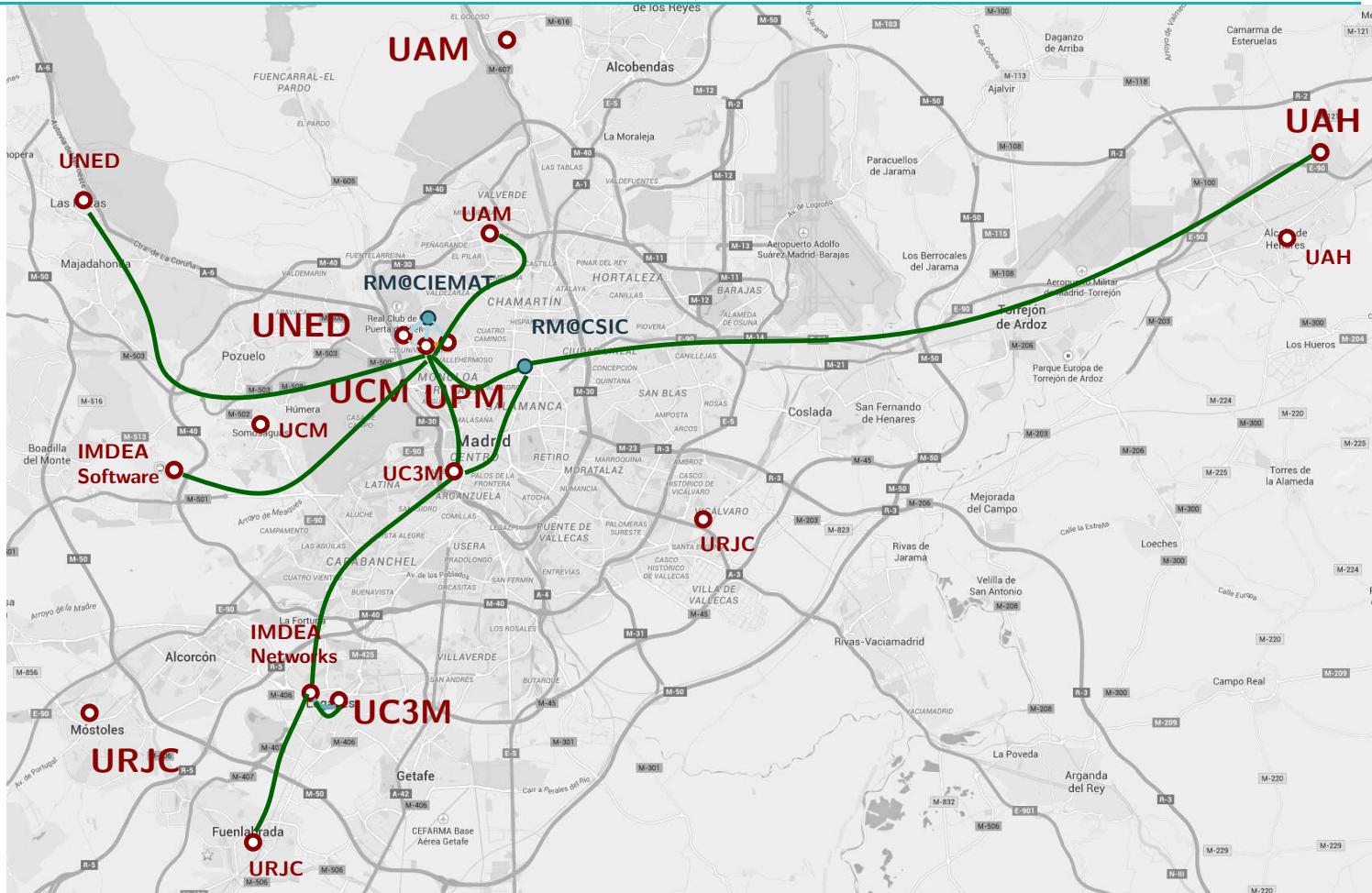
# Topología Física Objetivo (CORE)



# Topología Física 2025 (CORE + expansión)

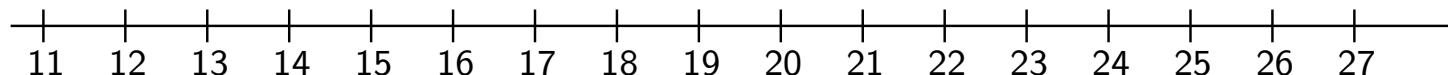


# Red Cuántica (MadQCI)

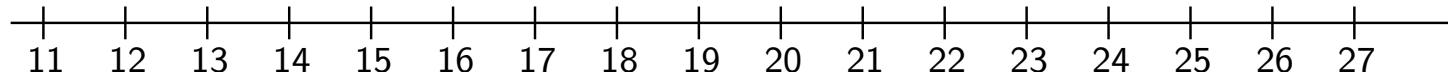


# Evolución (-2025)

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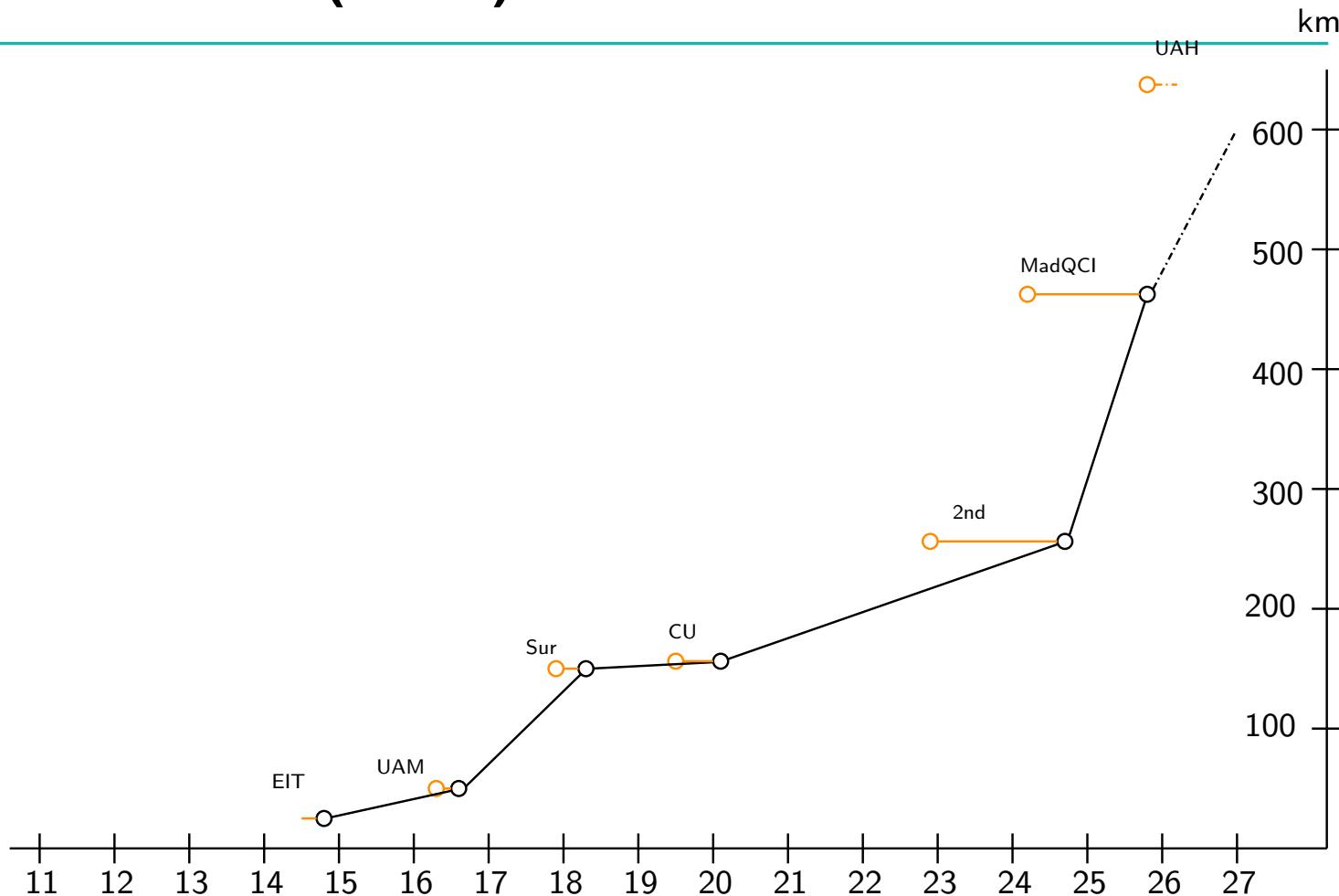
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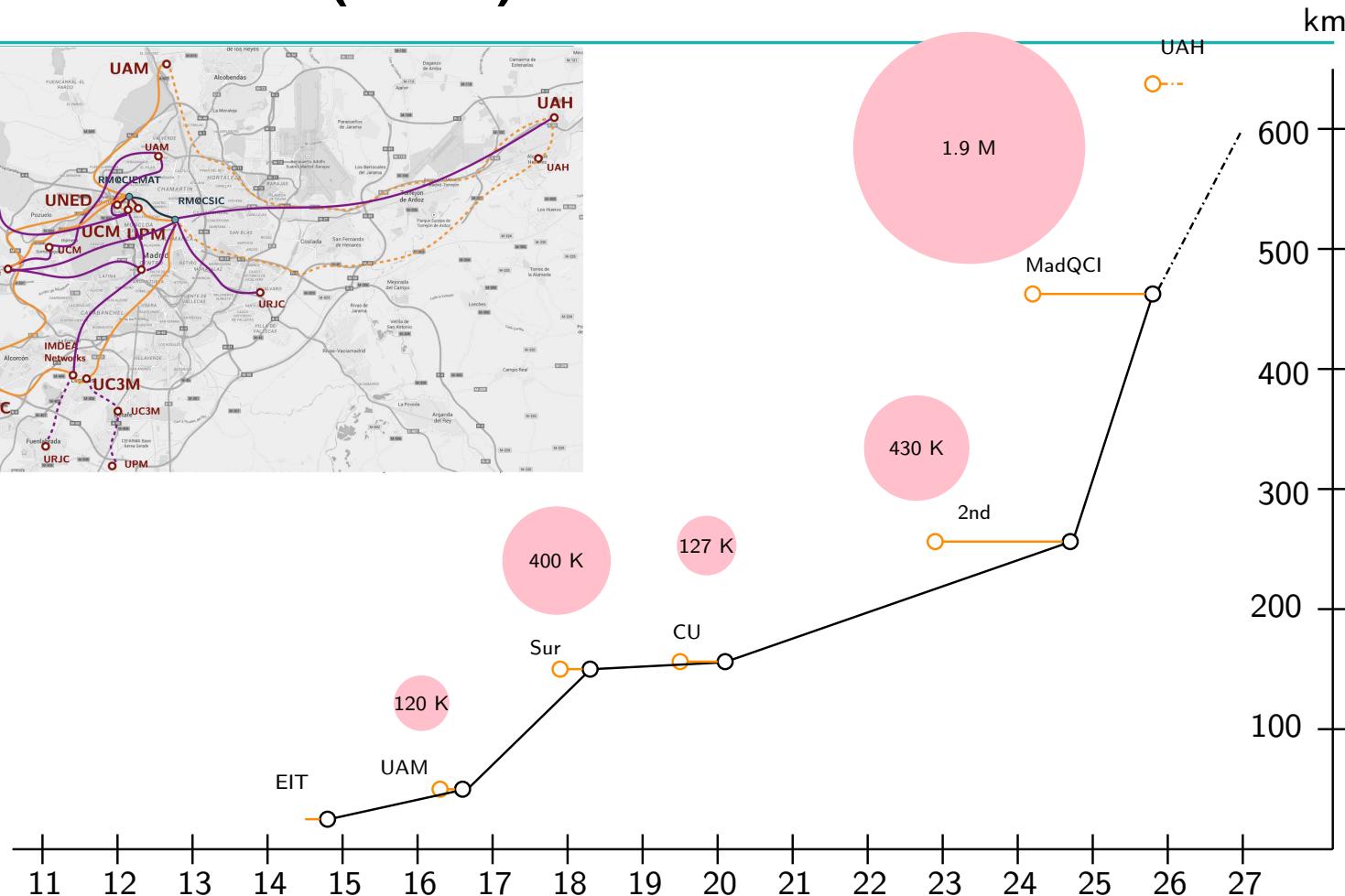
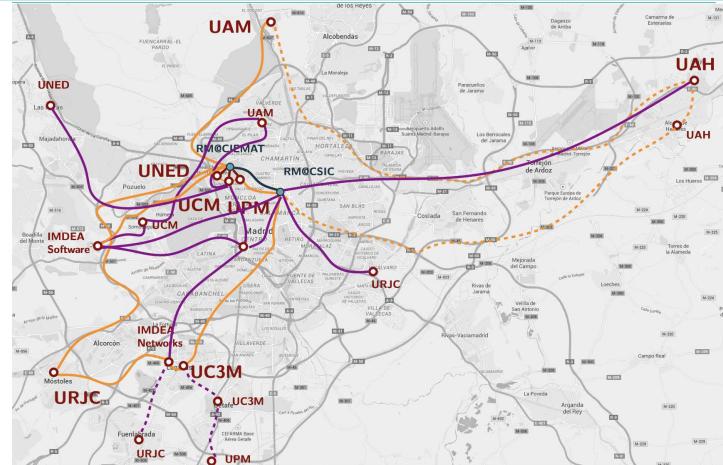
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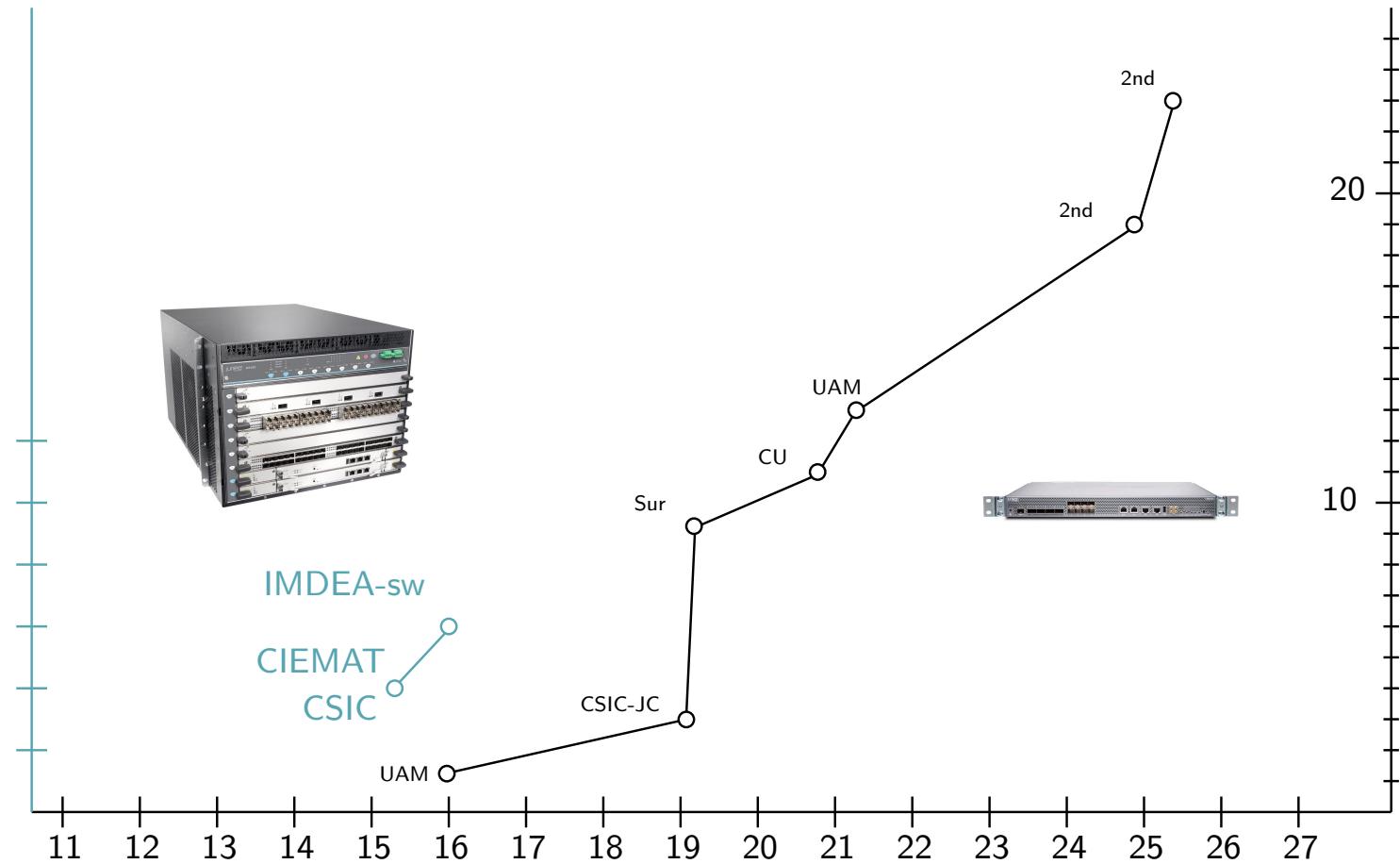
# Evolución (-2025). Fibra Oscura



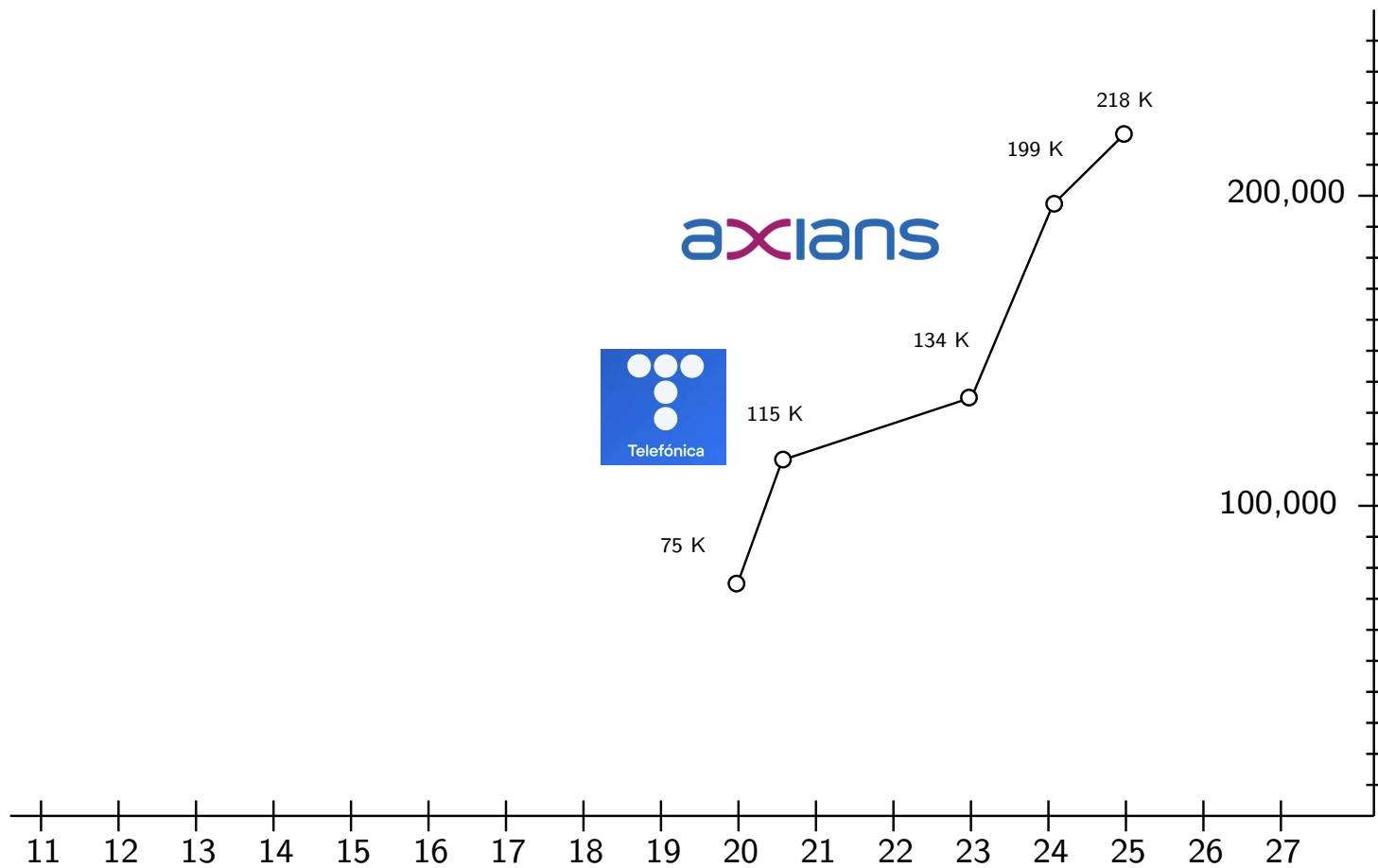
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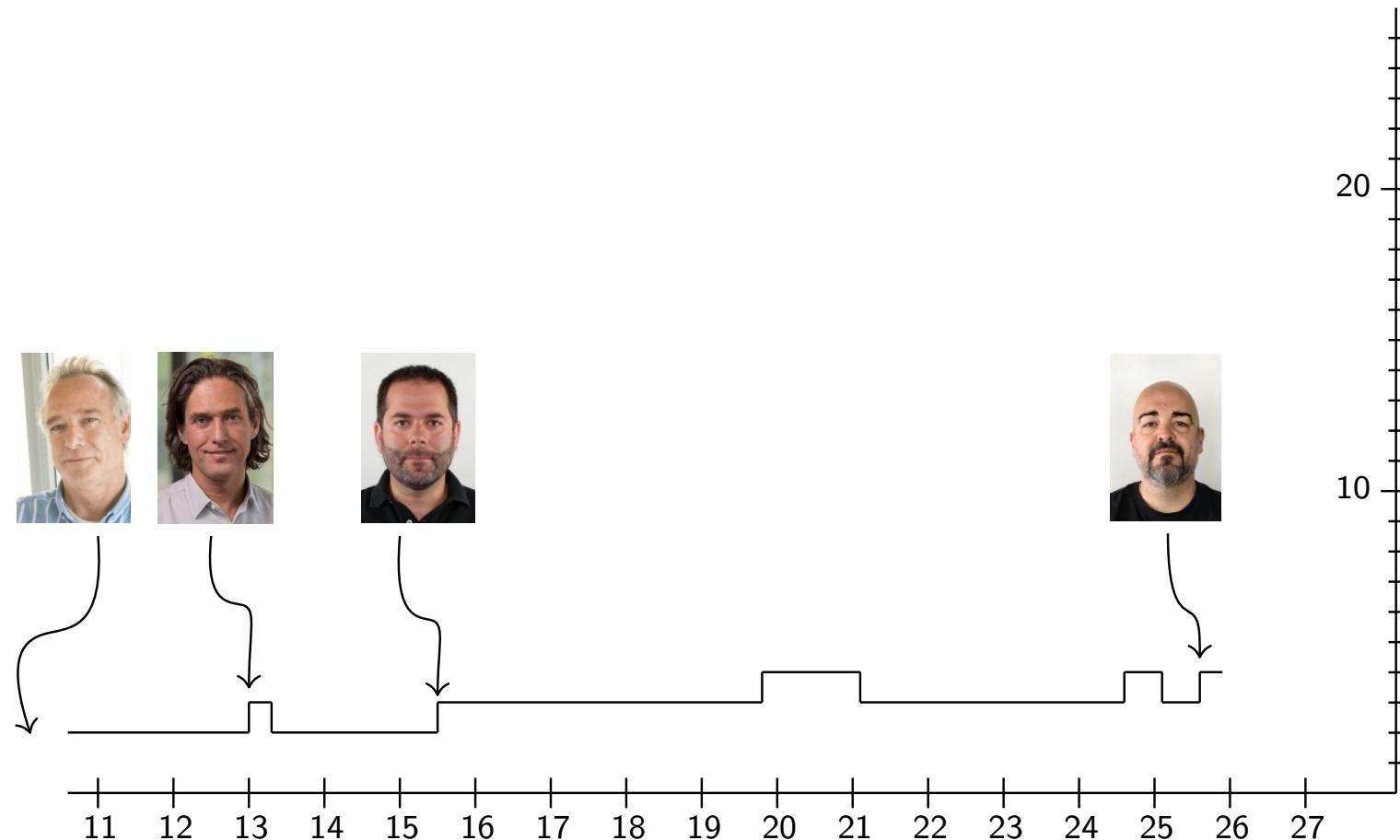
# Evolución (-2025). Equipos



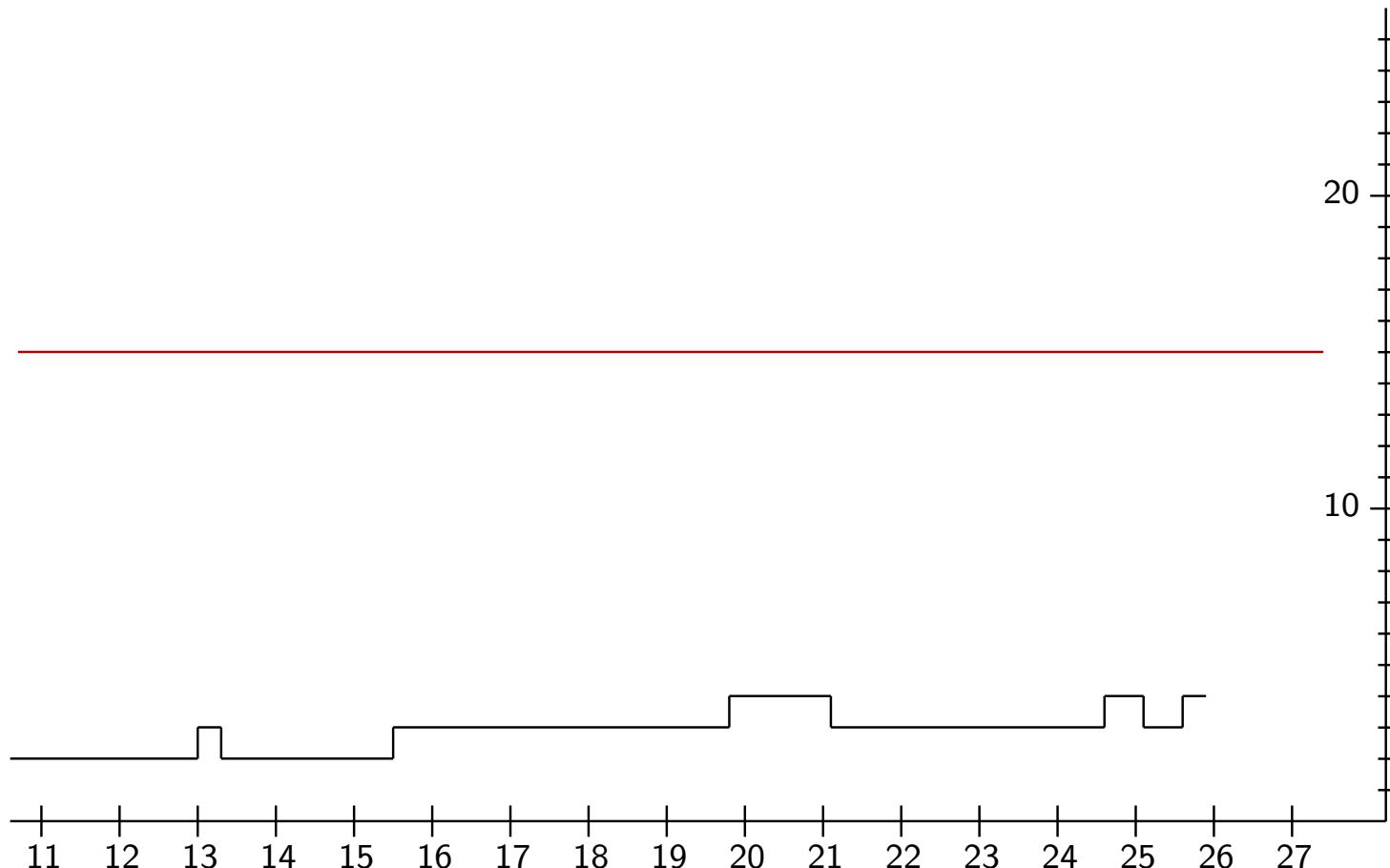
# Evolución (-2025). Externalización NOC



# Evolución (-2025). Personal



# Evolución (-2025). Personal



## Fase de despliegue ( -2020):

1. Completar la red troncal (UAH) → *en proceso de despliegue (RedIRIS)*

## Fase expansión (2024-26):

1. Backbone a 100GB (y transición progresiva a 100GB) → *en proceso (80%)*
2. Nuevas fibras oscuras (expansión) → *en proceso (90%)*
3. Nuevo CPD en IMDEA Software → *operativo*
4. Nueva red de investigación (MadQCI + ...) → *desplegada*

## Fase estable (2026-):

1. Alineamiento de IRUs
2. Seguridad
3. Investigación

# REDIMadrid en cifras (2025)

## Fibra oscura REDIMadrid:

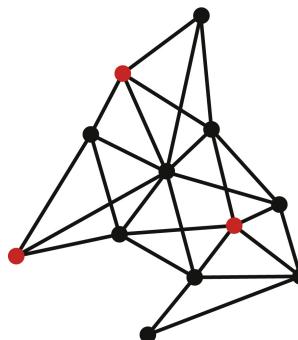
Total:  $\approx$  635km:



- 355 un par
- 280 dos pares



Correos Telecom



## Trafico cursado en REDIMadrid:

Total:  $\approx$  Picos de 65Gb/s

Todas las universidades con posibilidad de conexión a **100G**.

## Equipos de comunicaciones:

*Router instalados:* **20**, de los cuales 2 son P's y 2 son RR.

*Número total de equipos ópticos:* **9**

## Usuarios de REDIMadrid:

*Número total de usuarios:* 354.737

*Número total de mujeres:* 179.149(50.51%)

## AntiDDoS: Genie networks



# Capacidades Actuales (2025)

Entidades miembros de REDIMadrid	Velocidad de acceso
Conexión de REDIMadrid con RedIRIS en CSIC	100 Gbps (+)
Conexión de REDIMadrid con RedIRIS en CIEMAT	100 Gbps (+)
Conexión de REDIMadrid CSIC con REDIMadrid CIEMAT	200 Gbps
Consejo Superior de investigaciones Científicas (CSIC)	10 Gbps
Instituto CIB (Centro de Investigaciones Biológicas)	10 Gbps
Universidad de Alcalá de Henares (UAH)	10 Gbps / 10Gbps
Universidad Autónoma de Madrid (UAM)	10 Gbps / 10Gbps
LHCONE	10 Gbps (+100GBps)
Universidad Carlos III de Madrid (UC3M)	40 Gbps / 40 Gbps
Universidad Complutense de Madrid (UCM)	40 Gbps/ 40 Gbps
Universidad de Educación a Distancia (UNED)	10 Gbps/ 10 Gbps
Universidad Politécnica de Madrid (UPM)	100 Gbps / 100 Gbps / 10 Gbps
Universidad Rey Juan Carlos (URJC)	10 Gbps / 10 Gbps (+)
Instituto IMDEA Software	10 Gbps / 100 Gbps
Instituto IMDEA Networks	10 Gbps / 10 Gbps
Instituto IMDEA Energía	100 Mbps
Instituto IMDEA Nanociencia	1 Gbps
Instituto IMDEA Materiales	100 Mbps
Universidad Europea de Madrid	10 Gbps
Casa de Velázquez	1 Gbps
Universidad San Pablo CEU	10 Gbps
ESIC	1 Gbps
CUNEF	1 Gbps



# ¿PREGUNTAS?

thank you!

Abstract white line art consisting of several curved and intersecting lines, forming organic shapes against a teal gradient background. The lines are primarily white, with some thin black outlines.

**César Sánchez**

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**software**