Title of the Research

Methodologies and Protocols for Innovation and Interoperability between Internet of Things Standards in Home Automation

Ph.D. candidate

Muhammad Nouman

Cycle

Cycle XL(40th)

Tutors

Primary Tutor: Prof. Nicola Cordeschi (Politecnico di Bari)
Co-Tutors: Prof. Alessio Fascista (Politecnico di Bari)
Company Supervisor: Piero Boccadoro (Nextome Company)

(Include all tutors here, clearly identifying the primary one. If your scholarship involves a collaboration with a company, be sure to include a company tutor)

1. Description of the research program

This research focuses on the development of methodologies and protocols aimed at enhancing innovation and interoperability between various Internet of Things (IoT) standards, specifically within the domain of home automation. The main objective is to streamline communication and ensure seamless integration between different IoT devices and systems, regardless of their underlying standards or technologies, to improve the efficiency and scalability of smart homes.

The IoT ecosystem is diverse, with many standards such as Zigbee, Z-Wave, Wi-Fi, and Bluetooth, each serving different use cases. These diverse standards often create challenges for system integration and device interoperability. This research aims to bridge these gaps by developing protocols that allow devices to communicate seamlessly across different platforms. The focus will be on designing scalable and flexible solutions that ensure optimal performance even in complex, multi-device environments.

Key elements of the research include:

1. **Protocol Development**: Designing new communication protocols or enhancing existing ones to enable devices that use different standards to communicate effectively. This involves creating a middleware layer that abstracts the complexities of different IoT standards, allowing developers to focus on building applications without worrying about compatibility issues.
2. **Implementation and Testing**: Collaborating with Nextome S.r.l., the project will implement and test the proposed protocols in controlled smart home environments. This collaboration ensures that the solutions are not only theoretically sound but also practical and applicable in scenarios that simulate real-world conditions.
3. **Scalability and Security**: In addition to ensuring interoperability, the research will focus on optimizing the scalability of the IoT systems. This includes handling large volumes of data from multiple devices and ensuring that the network remains secure and efficient as the number of connected devices grows.
4. **Cross-domain Applications**: The developed protocols will not only be limited to smart home environments but will also be tested in other domains such as smart cities and healthcare. These cross-domain applications will demonstrate the versatility and generalizability of the solutions, ensuring that they can be used in a wide range of IoT ecosystems.
5. **Impact on Future Standards**: By providing innovative solutions to current interoperability issues, this research has the potential to influence future IoT standards. The results could lead to new frameworks or protocols that are adopted by international standardization bodies, further contributing to the advancement of the IoT industry.

The ultimate goal is to contribute to the advancement of smart home technologies by improving device compatibility, system scalability, and security. Through this project, the research will provide novel solutions to real-world challenges and pave the way for more interconnected and intelligent IoT systems.

2. Schedule of the research activities

Insert the research activities that you plan, or you have completed for the three years, including any period abroad. Note that:
- If your scholarship is funded through a ministerial program, a minimum of six months abroad is required.
- If your scholarship involves a collaboration with a company, you are required to spend at least six months working within the company.

First academic year (completed/planned)

	Description	Period	Activity abroad
Insert name of first research activity	**Literature Review and Gap Identification.** Conduct a literature review to identify gaps in existing methodologies and proposed approaches for ensuring IoT interoperability in home automation systems.	November 2024 – March 2025	**NO**
Insert name of second research activity	**Collaboration with Nextome S.r.l. for IoT Protocol Testing** Engage in hands-on work at Nextome S.r.l. from April to June 2025 to implement and test the proposed IoT interoperability protocols. During this period, I will collaborate with Nextome S.r.l., focusing on IoT standards and interoperability. This collaboration will ensure that the validation of IoT solutions is robust and tested across various environments, extending beyond the scope of home automation. After the initial three months with Nextome S.r.l., I will focus on collecting and organizing extensive data on IoT protocol performance from July to October 2025 for thorough validation.	April 2025 – October 2025 Collaboration with Nextome S.r.l. April to June 2025	**NO**

Second academic year (completed/planned)

	Description	Period	Activity abroad
Insert name of first research activity	**Manuscript Preparation and Results Reporting.** After conducting hands-on experiments at Nextome and collecting the results, I will prepare a manuscript for submission to a peer-reviewed journal and conference. The paper will detail the process from theoretical development to hands-on testing with Nextome S.r.l., demonstrating the interoperability of IoT devices and contributing to advancements in smart home automation.	November 2025 – May 2026	**NO**
Insert name of second research activity	**Research Stay Abroad for IoT Standards Testing and Validation** The proposed research stay at Pompeu Fabra University, under Prof. Boris Bellalta, will test and validate IoT standards for smart home networks, focusing on improving device interoperability and communication. Additionally, the research will explore adapting these standards to broader applications, like smart cities and healthcare, aiming to expand their impact across various IoT-driven sectors.	June 2026 – December 2026	**YES**

Third academic year (completed/planned)

	Description	Period	Activity abroad

Insert name of first research activity	**Optimization and Final Validation of IoT Solutions** The final phase of the research will focus on optimizing and validating the IoT solutions developed in previous years. A thesis advisory committee comprising academic and industry experts will be established to provide feedback and guidance. This will help ensure that the thesis aligns with industry standards and addresses practical challenges in IoT systems.	January 2027 – May 2027	**NO**
Insert name of second research activity	**Final Collaboration with Nextome S.r.l. for Deployment and thesis Completion.** Test the scalability of the developed IoT solutions from June to August 2027 to ensure they are applicable to large-scale environments and multi-device ecosystems. This activity will be essential for the real-world application of the research.	June 2027 – October 2027 Collaboration with Nextome S.r.l. (June to August)	**NO**

3. Training and research activities plan

Ph.D. students are required to carry out activities for an amount of 60 ECTS (CFU) per year, for a total of 180 ECTS throughout the academic course. The activities carried out by Ph.D. students are divided into:

- **Didactic activities:** min 36 – max 60 ECTS (of the total 180 ECTS), preferably in the first two years of the course.
- **Research activities:** min 120 – max 144 ECTS (of the 180 total ECTS)

The ECTS related to the **didactic activity** can be obtained, for instance, by attending courses and seminars from graduate schools or master's degree programs. The DAUSY teaching-course catalogue (http://dausy.poliba.it/Ph.D./teaching-course-catalogue/) comprehends a list of didactic activities that can be included in this plan. Didactive activities are divided into:

A. **Ph.D. courses:** these are courses offered at the Ph.D. level usually by doctoral schools (e.g., DAUSY Courses, Poliba ScuDo Courses, SIDRA Summer School Courses, EECI IGSC Courses, Partner Universities Ph.D. Courses, etc.).
B. **Master's degree courses**: maximum 18 ECTS can be obtained by master's degree courses or single-cycle degree courses if these have not been attended by the Ph.D. student during his/her second level education.
C. **Soft skills:** maximum 12 ECTS can be obtained by courses classified as "soft skills" after the authorization of the Academic Board.
D. **Participation to seminars**: participation to seminars related to the research program is considered as a didactic activity (5 hours of seminar = 1.5 ECTS).
E. **Participation to international congresses or workshops**: participation at international congresses and workshops is considered as a didactic activity (1 international congress/workshop day = 1 ECTS).
F. **Presentation of research products at international congresses or workshops:** presentation of a research product at international congresses and workshops is considered as a didactic activity (1 presentation = 2 ECTS).

Note that:

- **At least 18 ECTS (of the total 180 ECTS) of didactic activities (A) and (B) must be obtained by completing a final exam**.
- For all courses (A) and (B) the 50% of the total course ECTS is recognized in case the final exam is not completed.
- Didactic activities must be confirmed with attendance certificates.

Examples:

- A 6-ECTS course, given in a master's degree course, can be attended by the Ph.D. student who can receive 3 ECTS if he/she does not complete the final exam (in this case the attendance must be certified).
- If a Ph.D. student attends a 5-day conference presenting a scientific contribution, he/she will obtain 5 ECTS for the participation and additional 2 ECTS for the conference contribution (the certification is required for both the attendance and the presentation).

Please refer to the *"Educational regulations of the Doctoral School of Politecnico di Bari"* for more details
http://www.poliba.it/sites/default/files/dottorati/regscudopoliba.pdf

The ECTS related to the **research activities** are divided into:

     G.   **Individual research activity.**
     H.   **Supervision of students:** tutoring activities for students in undergraduate and master's degree programs.
     I.   **Integrative teaching activities:** supplementary teaching activity (e.g., seminars, courses, practical exercises, etc.) for students in undergraduate and master's degree programs within the limit of 40 hours per academic year.
     J.   **Preparation of manuscripts for conferences or journals.**

Note that each ECTS usually corresponds to 25 hours of research activity.

First academic year (completed/planned)

		Description	Period	Final Exam	ECTS
A.	**Ph.D. courses**	Introduction to Autonomous Systems	23/06/2025-30/06/2025	Yes	1
		Data-driven fault Diagnosis and Fault Prognosis	01/07/2025-10/07/2025	Yes	1
		Human utonomous System Interaction	28/02/2025-28/03/2025	Yes	1
		Intelligent Supervisory Systems	08/01/2025-30/01/2025	Yes	2
B.	**Master's degree courses**	Internet of Things	04/10/2024 – 19/01/2025	Yes	6
		Information Systems Design and Big Data	10/10/2024-11/01/2025	No	6
C.	**Soft skill courses**	Research Writing and Communication Skills	TBD	No	3
D.	**Participation to seminars**	Innovations in Sustainable Energy Conversion Technologies Seminars offered by DAUSY 2024/2025	03/12/2024-04/12/2024 TBD	No	1
E.	**Participation to international congresses or workshops**	International Workshop on Digital Factories ISM (Prague, Czech Republi)	20/11/2024 - 22/11/2024	No	3+3
		DCOSS-IoT 2025 (Distributed Computing in Smart Systems and the Internet of Things) Tuscany (Lucca), Italy	09/06/2025-11/06/2025		
F.	**Presentation of research products at international congresses or workshops**	DCOSS-IoT 2025 (Distributed Computing in Smart Systems and the Internet of Things) Tuscany (Lucca), Italy	09/06/2025-11/06/2025	No	2
		TOTAL OF ECTS FOR TRAINING ACTIVITIES			29
G.	**Individual research activity**	Literature Review and Gap Identification, Theoretical Framework Development, Collaboration with Nextome S.r.l. for IoT protocol testing, Data Collection and Initial Analysis.	November, 2024-October, 2025	No	25
H.	**Supervision of students**				
I.	**Integrative teaching activities**				
J.	**Preparation of manuscripts for conferences or journals**	Initial literature review and development of methodology paper.	November, 2024-October, 2025	No	6
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			31
		TOTAL OF ECTS			**60**

Second academic year (completed/planned)

		Description	Period	Final Exam	ECTS
A.	Ph.D. courses	Simulation Systems for Engineering Applications	TBD	Yes	1
		Physical Layer Security for wireless communication	TBD	Yes	1
		Distributed/Decentralized Control and Optimization of Large-Scale Systems	TBD	Yes	1
		Fundamentals of Radio Localization and Sensing,	TBD	Yes	1
B.	Master's degree courses	Base di Dati	TBD	TBD	6
				Yes/No	
C.	Soft skill courses	Soft skill course offered by DAUSY 2025/2026	TBD	Yes/No	3
D.	Participation to seminars	Seminars offered by DAUSY 2025/2026	TBD	No	1
E.	Participation to international congresses or workshops	International Conference on the Internet of Things (IoT 2026)	TBD	No	3
F.	Presentation of research products at international congresses or workshops	International Conference on the Internet of Things (IoT 2026)	TBD	No	2
		TOTAL OF ECTS FOR TRAINING ACTIVITIES			19
G.	Individual research activity	Manuscript Preparation and Results Reporting, Cross-domain Exploration (Smart Cities, Healthcare), Advanced Testing and Validation, Optimization of IoT Solutions	November, 2025- October, 2026	No	32
H.	Supervision of students				
I.	Integrative teaching activities				
J.	Preparation of manuscripts for conferences or journals	Submission of results to journals and conferences	November, 2025- October, 2026	No	9
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			41
		TOTAL OF ECTS			**60**

Third academic year (completed/planned)

		Description	Period	Final Exam	ECTS
A.	Ph.D. courses			Yes/No	
				Yes/No	
				Yes/No	
B.	Master's degree courses			Yes/No	
				Yes/No	
C.	Soft skill courses	Soft skill course offered by DAUSY 2026/2027	TBD	Yes	3
		Seminars offered by DAUSY 2026/2027	TBD	No	1

D.	**Participation to seminars**				
E.	**Participation to international congresses or workshops**	Industry of Things World 2027 (Berlin, Germany)	TBD	No	3
F.	**Presentation of research products at international congresses or workshops**	Industry of Things World 2027 (Berlin, Germany)	TBD	No	2
		TOTAL OF ECTS FOR TRAINING ACTIVITIES			9
G.	**Individual research activity**	Final Optimization and Validation of IoT Solutions, Collaboration with Nextome S.r.l. for Deployment, Thesis Preparation, Presentation of Results.	November, 2026- October, 2027	No	35
H.	**Supervision of students**	Mentoring, Project Supervision, Research Guidance, Feedback, Student Project Evaluation, Technical Support.	November, 2026- October, 2027	No	6
I.	**Integrative teaching activities**	IoT Teaching, Practical Exercises, Knowledge Sharing, System Interoperability, Student Engagement,	November, 2026- October, 2027	No	3
J.	**Preparation of manuscripts for conferences or journals**	Final publications covering optimization, deployment, and thesis findings	November, 2026- October, 2027	No	7
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			51
		TOTAL OF ECTS			**60**

4. List of the publications written by the candidate in the triennium

Insert the list of papers written during the Ph.D. program. If the paper is still not published indicate its status (e.g., submitted, under review, under 2nd review round, accepted to appear, etc.).

International Journal Articles

   [j1]   N/A

International Conference Proceedings

   [c1]   N/A

Insert Ph.D. candidate name

___Muhammad Nouman___

Insert Tutor 1 name and title

_ Nicola Cordeschi, Assistant Professor _

Insert Tutor 2 name and title

_ Alessio Fascista, Assistant Professor_