Daniela Tulone

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PROFILE: Enterprising and creative professional with extensive experience in wireless sensor networks, distributed systems, and algorithms. Advanced degree in Computer Science and Mathematics driven by a vivid interest in designing innovative solutions for real-world problems. Proven ability to successfully lead projects and work in interdisciplinary and international teams. Strong problem-solving and analytical skills.

AREAS OF EXPERTISE: Wireless sensor networks (WSN), algorithms, smart grids, secure distributed systems, data management/analysis, dynamic trade-offs between system performance and robustness, and predictive models. Recent work includes real-time monitoring and anomaly detection/analysis, energy efficiency, quality of service, demand/response management, integration of renewable sources, security in industrial wireless systems.

PROFESSIONAL EXPERIENCE

- **Freelancer**, Milan, Italy. September 2012–present.

  – Collaborated with R&D labs and SMI on innovative projects in the field of real-time monitoring, energy efficiency, and water monitoring.

  – Inventor of the **SmartEnv system**, an innovative middleware system for monitoring and analyzing at real-time physical phenomena using heterogeneous WSN. SmartEnv is innovative with respect to commercial products and research prototypes for: (1) always providing guarantees on the service quality, (2) distinguishing at real-time between sensor malfunctioning and external events, (3) consuming little energy and being dynamically adaptable. The system is ready to undergo technology transfer.

- **European Commission, Joint Research Center.**
  Scientific Officer, Ispra, Italy. February 2009–August 2012.
  – Promoted a project on the security of industrial wireless systems. Analyzed security threats and vulnerabilities present in WirelessHart and ISA100.11 emerging standards (e.g., jamming, DoS attacks).
  – Designed an innovative tool for underwater sensor monitoring that tolerates periods of intermittent connectivity and temporal communication disruptions using predictive models.
  – Contributed to the definition of EU guidelines on port security.

- **Engineering Ingegneria Informatica, R&D Division.**
  Research Lab Leader, Rome, Italy. October 2007–November 2008.
  Responsible for the initial start-up of a new R&D lab on wireless networks. Duties included the definition of short and medium-term objectives and funding. Established within 6 months several collaborations with European industrial and academic partners for the definition of collaborative projects.

- **MIT, Computer Science and Artificial Intelligence Laboratory.**
  Ph.D. Student, Cambridge, USA. November 2004–December 2005.
  Post-Doc Researcher, Cambridge, USA. January 2006–September 2006.
  Visiting Researcher, Center for Embedded Networked Sensing, UCLA. October 2006–June 2007.
  Promoted a few research projects on WSN and mobile networks (e.g., energy conservation, time estimation in low-power networks, and data consistency in vehicular networks). Proposed a novel adaptive WSN system for answering on-line queries, detecting anomalies and data similarities.

- **C.N.R. and Computer Science Department, University of Pisa.**
  Research Associate, Pisa, Italy. November 2002–November 2004.
  Proposed the first secure distributed fine-grained time-stamping system, which is particularly suitable for real-time applications and for time–based access control of critical resources (Best paper). Responsible for a project on the design of user-tunable trade-offs between security and system performance.

- **Bell–Laboratories, Secure System Research Department.**
  Research Staff Member, Murray Hill, NJ, USA. January 2000–October 2002.
  Responsible for the design and implementation of a novel secure and highly scalable distributed data repository that is resilient to malicious coordinated attacks.

- **AT&T Labs, WorldNet Internet Department.**
  Software Engineer, Holmel, NJ, USA. February 1998–December 1999.
  Led the design, implementation and deployment of a 3-tier help-desk and a web-based system to support AT&T business. All of these systems successfully went into production.

- **New York University, Courant Institute of Mathematical Sciences.**
  C.N.R. Exchange Researcher, New York, USA. September 1996–December 1997.
  Proposed the first polynomial-time probabilistic method to prove geometric conjectures. The system has been part of the open-source CORE package since 1999.
- **University of Catania, Department of Mathematics.**
  C.N.R. Associate Researcher, Catania, Italy. February 1995–May 1996.

EDUCATION

- **Ph.D., Computer Science.** January 2003–December 2005.
  University of Pisa (Italy) jointly with Massachusetts Institute of Technology (USA).
  Thesis: *Mechanisms for energy conservation in wireless sensor networks.*
- **M.S., Computer Science.** September 1996–January 1998.
  Courant Institute of Mathematical Sciences, New York University (USA). GPA 3.9/4.0.
- **Master in Industrial Modeling.** March 1994–November 1994.
  University of Catania (Italy), University of Kaiserslautern (Germany), and IBM.
  Entrance limited to 15 post-graduates determined by a competitive exam. Final exam score 60/60.
- **B.S. and M.S., Mathematics.** November 1989–March 1994.
  University of Catania. Graduated with the highest honors (110/110 *cum laude*).
  Thesis: *ETNA, Extensible Theorem Prover in NAtural deduction, in Set Theory.*

ADDITIONAL POST-GRADUATE SCHOOLS

- **Advanced School on Cryptography.** Barcelona (Spain). February 2004.
  Department of Mathematics, Universitat Politecnica de Catalunya.
- **Advanced School on Mobile Computing.** Pisa (Italy). September 2003.
  Scuola Normale Superiore. Entrance limited to 30 international young researchers.
- **Advanced School on Computational Complexity.** Cortona (Italy). July 1995.
  Scuola Matematica Interuniversitaria. Title: *Computational Complexity.*
  Entrance limited to 20 international Ph.D. students and young researchers.

HONORS AND AWARDS

- Awarded one of the 2 positions for Visiting Assistant Professor at UCLA (about 60 candidates). April 2007.
- **Best paper award.** IEEE ICC, Network Security and Information Assurance Symposium.
  D. Tulone. *A secure and scalable digital time-stamping service*, June 2006.
- **Ph.D. grant from University of Pisa.** November 2002.
  Awarded **one of the 6** Ph.D. grants from the University of Pisa for the academic years 2003–2005.
- Selected for the **MIT-Italy program** for the years 2004–2005.
- **C.N.R. (Italian National Research Council) research grant.** October 2002.
  Awarded a research grant to perform research at the ISTI CNR, Pisa.
- **C.N.R. research fellowship.** October 1995.
  Awarded **one of 8** fellowships from C.N.R. to perform research abroad. This fellowship was determined through **national competition**.
- **C.N.R. research fellowship.** December 1994.
  Awarded **one of 10** fellowships from C.N.R. to conduct research on Computer Algebra. This fellowship was determined through **national competition**.
- **Consorzio Archimede (University of Catania and IBM) grant.** March 1994.
  Awarded **one of** 15 grants from Consorzio Archimede to work on Mathematical models.

RESEARCH PROJECTS

WSN monitoring.

- **SmartEnv: a real-time monitoring system with quality guarantees (ongoing).**
  WSNs are known for their potential to remotely observe phenomena at high resolution and at reasonable costs. However, sensor faults, communication failures, and unexpected events can affect the quality of the observations and lead to misleading conclusions (e.g., false alarms). Moreover, it is challenging to analyze at real-time the large volume of streaming data produced

at sensors. These problems have been successfully addressed by SmartEnv, an innovative sensor-based middleware system for monitoring and analyzing at real-time physical/chemical attributes with quality guarantees. SmartEnv is able to: (1) answer queries on past, current, and future behavior of the phenomenon, (2) analyze at real-time sensor data and derive data properties (e.g., trends, correlations. data similarities), and (3) detect/diagnose at real-time data anomalies.

SmartEnv is innovative with respect to current systems for: (1) providing guarantees on the quality of the observations even in the face of temporal communication disruptions, sensor malfunctioning, and data instability, (2) analyzing the high volume of sensor data at real-time and distinguishing between sensor malfunctioning and external events, (3) consuming little energy and being dynamically adaptable. Preliminary experiments performed over a set of real-world sensor data (e.g., temperature, pressure) indicate its effectiveness.

Moreover, SmartEnv can assist **sensor deployment** (i.e., compute the number and position of sensors to be deployed in order to get probabilistic guarantees on the quality of the future monitoring service). It is under patent evaluation and ready to undergo technology transfer.

– **SAF: an energy-efficient system for answering queries via time series forecasting.**
with Sam Madden (MIT)

In this project we proposed an energy-efficient and adaptable WSN system, called *SAF*, for approximately answering user queries at the sink and for detecting anomalies and data similarities based on time series forecasting [4, 6, 18, 22]. SAF relies on a class of lightweight and adaptable time series models built at sensors, and on a suite of novel algorithms for monitoring and adapting the prediction models, and for detecting local data anomalies and node similarities at no additional communication cost. This is obtained using a novel definition of node similarity based on data models, and an efficient clustering algorithm that is optimal in the number of clusters. SAF offers several benefits: it consumes very little energy, provides data guarantees, and dynamically adapts to variations in the environmental conditions and user requirements.

– **A scheme for disruption-tolerant underwater sensor monitoring.**

Underwater sensor networks have the potential to enhance our ability of observing and monitoring underwater physical phenomena, warning against natural disasters, and protecting critical areas. However, the adverse underwater conditions and the limitations of underwater acoustic communication, such as its volatile link quality and temporal node isolation, remarkably affect the quality of on-line monitoring. We analyzed the problem of designing a disruption/delay tolerant querying system for underwater sensor networks, and proposed a model-based monitoring scheme that provides probabilistic guarantees in the presence of transient communication disruptions [10].

– **A general on-line fault detection and diagnosis system.**
with Mani Srivastava (UCLA)

The information provided by WSN monitoring systems must be of high quality for them to be effective. This is a challenging task in low-cost WSN since sensors are error-prone, limited in their energy supply, CPU, memory and bandwidth, and sensitive to environmental variations. Moreover, physical phenomena evolve over the time and are seldom distributed homogeneously. We proposed an on-line model-based fault-detection system, called *Inspect*, that is able to detect sensor malfunctioning at real-time and distinguish among stuck-at faults, spikes, outliers and miscalibrations by exploiting spatial-temporal correlations [9]. Inspect have a wide applicability and can work in synergy with SAF, thus enhancing its robustness.

On-going projects on smart grids monitoring built on top of SmartEnv.

– **Water networks monitoring.** The percentage of water dispersed in water networks before reaching destination reaches high peaks in some regions due to aging infrastructure and poor maintenance (e.g., in South Italy exceeds 40%). The aim of this project is to design a system for monitoring at real-time physical parameters along critical parts of the network and detecting water leaks using heterogeneous WSN. The system, which is built on top of SmartEnv, is designed to localize leaks and schedule maintenance according to the severity of the faults detected.

– **Forecast of photovoltaic production.** This project aims at enhancing the prediction of PV power generation by using a network of heterogeneous wireless sensor nodes, which monitors physical parameters at fine-grained, detect trends and analyzes correlations between power produced/uncertainty and environmental conditions. Our focus is also in studying the impact of clouds on the produced power and try to predict it by means of real-time WSN monitoring.

– **Maximization of PV power usage.** The focus of this project is on maximizing power produced by photovoltaic panels for residential buildings by monitoring and predicting both the PV power produced and user demand, and assisting users in scheduling their tasks.

Security in wireless networks.

– **Security of industrial wireless systems and emerging standards.**
Industrial wireless systems are drawing increasing attention for their numerous advantages, such as installation and maintenance cost savings, rapid deployment, and improved control information, but are also rising new security concerns. This project analyzes threats and vulnerabilities inherent to the WirelessHart and ISA100.11 industrial wireless standards, which arise at different layers of the network stack, and concern the design of some crucial building blocks, and unexplored security threats (e.g., node failures, intruders, and malicious coordinated attacks). We analyzed scenarios of successful malicious attacks exploiting limitations inherent in the wireless networks such as limited energy and network bandwidth. For instance, we showed how a targetable jamming attack can affect the correctness of the time module, thus disrupting the availability and the correctness of the underlying service.

Building blocks in WSN.

– **High-precision and energy-efficient time estimation.**
Time synchronization plays a crucial role in real-time monitoring, node coordination, data aggregation, and in many networking tasks. We studied the time synchronization problem from a *novel perspective*, which is complementary to the well-studied clock synchronization problem and consists of reducing the error growth between consecutive synchronization using clock information [1,7,13]. We proposed a suite of deterministic and probabilistic protocols that are both of *theoretical* and *practical* interest. In fact, they lead to a refinement of the *optimality bound* for external clock synchronization, and they can be applied to: (1) conserve energy in long-lived sensor applications, (2) improve the clock accuracy by a few constant factors, and (3) enhance the robustness of the clock in case of network partitions.

– **Conserving energy and enhancing QoS via Quorum Systems.**
with Erik Demaine (MIT)
Scalability and energy conservation are key issues in long-lived large WSNs. We studied ways to enhance the performance of large WSN systems by analyzing for the first time quorum systems (a known technique to improve the performance of distributed systems) in the specific context of sensor networks and energy conservation. More precisely, we showed the unsuitability of quorum systems proposed for wired networks, revised them along with their metrics by taking into account sensor limitations, and proposed a novel class of quorum systems tailored for WSN [8,22].

Mobile networks.

– **Data consistency in highly mobile networks.**
Ensuring strong consistency guarantees on shared data in highly mobile networks is a challenging problem, which is crucial in several network tasks requiring node coordination (e.g., low duty cycle, object tracking, routing assistance). We studied under which mobility conditions it is possible to ensure strong consistency data guarantees when node paths and speed are unknown (e.g., in vehicular networks), and provided a *minimum set* of mobility constraints that are satisfiable also in case of low density networks [2,5]. We also proposed a novel class of quorum systems that is *provably optimal* in terms of communication costs and that does not violate the consistency property in case of high mobility. Simulation results based on the restricted random waypoint on a city section had indicated the suitability of our proposal also to vehicular networks.

Secure distributed computing.

– **A secure and scalable real-time digital time-stamping system.**(Best paper award)
Secure digital timestamps play a crucial role in many applications that rely on the correctness of time sensitive information. Previous time-stamping systems were based on *linking schemes*, which provide a relative temporal order, but have coarse granularity, high latency, and scale poorly to high volume of clients and requests. As a result, they are not suitable for applications requiring real-time fine-grained timestamps (e.g., stock trading, e-auctions, aggregation of real-time sensitive information, and temporal access control). We proposed a novel *provably correct* scheme based on real-time timestamps and Byzantine quorum systems, which overcomes those drawbacks and improves the system performance [11, 13]. Its fine granularity, improved scalability and efficiency make our scheme particularly suitable for real-time applications.

– **The Fleet system.**
with Mike Reiter (CMU) and Dahlia Malkhi (Microsoft Research)
Fleet was a novel middleware system implementing a secure distributed data repository for persistent objects [16]. It is primarily targeted for supporting critical applications such as governmental

and financial applications, e-banking, and it is designed to be highly available and scalable to very large numbers of clients and servers. It employs Byzantine quorum systems to improve the performance of the system (e.g., scalability, load balance, access cost per operation), and comprises a suite of novel intrusion-tolerant coordination protocols. We built an e-voting application on top of Fleet and deployed it to DARPA in September 2001.

– **Efficiency and scalability in intrusion-tolerant data consistency protocols.**
Distributed coordination protocols that are resilient to malicious attacks are known to have high computational and communication cost. We studied ways to improve their efficiency and scalability in case of very large data by means of a randomized approach combined with one-way collision-resistant hash functions [12, 23], and an optimistic information dispersal protocol that dynamically adapts as failures are detected [20]. We also explored weaker data consistency models, such as causal consistency in a shared memory [15] and in dynamic client/server models [14].

Randomized automatic theorem proving.
with Chee Yap (NYU)

– We studied the problem of efficiently proving/disproving conjectures in Set Theory [25] and Geometry [3, 17]. More precisely, we proposed a novel hybrid symbolic-numerical method that proves the validity of a geometric conjecture *by examples* (i.e., generating instances of its construction). Our work led to the *first polynomial-time* probabilistic method for proving conjectures in Geometry. The system has been part of the open-source Core package since 1999.

PUBLICATIONS

Journals

1. D. Tulone. *On the feasibility of global time estimation under isolation conditions in wireless sensor networks.* Algorithmica, 49(4), pp. 386-411.
2. D. Tulone. *Ensuring data consistency in highly mobile networks via quorum systems.* In Ad Hoc Networks, vol. 5, issue 3, pp. 1251-1271.
3. D. Tulone, C. K. Yap, C. Li. *Randomized zero testing of radical expressions and Elementary Geometry theorem proving.* In Automated Deduction in Geometry, LNCS 2061, pp. 58–82, Springer 01.

Conferences

Wireless sensor networks:

4. D. Tulone, S. Madden. *An energy-efficient querying framework in sensor networks for detecting node similarities.* In Proc. of the 9th Intl. ACM Symp. on Modeling, Analysis and Simulation of Wireless and Mobile Systems, pp. 191–300, Oct 06.
5. D. Tulone. *Is it possible to ensure strong data guarantees in highly mobile networks?* In Proc. of the 5th Annual Mediterranean Workshop of Ad hoc Networks (MedHoc), Jun 2006.
6. D. Tulone, S. Madden. *PAQ: Time series forecasting for approximate query answering in sensor networks.* In Proc. of the 3rd European Conf. in Wireless Sensor Networks, pp. 21–37, Feb 06.
7. D. Tulone. *A resource–efficient time estimation for wireless sensor networks.* In Proc. of the 4th ACM Workshop of Principles of Mobile Computing, pp. 52–59, Oct 04.
8. D. Tulone, E. Demaine. *Redesigning quorum systems for energy conservation in sensor networks.* In Proc. 2nd Intl. Conf. on Wireless Algorithms, Systems, and Applications, pp. 147–157, Aug 2007.
9. D. Tulone, M. Srivastava. *Inspect: a General Framework for On-Line Detection and Diagnosis of Sensor Faults.* In Proc. of ITA Conf., Sept 07.
10. D. Tulone. *A Model-based Monitoring Scheme for Disruption-tolerant Underwater Sensor Networks.* Short paper. In Proc. of 6th IEEE Conf. on Sensors, Mesh and Ad hoc Networks (SECON), June 2009.

Secure distributed computing:

11. D. Tulone. *A secure and scalable digital time–stamping service.* In Proc. of the IEEE Intl. Conf. on Communications (ICC): Network Security and Information Assurance Symp., Jun 06. **Best paper**.
12. D. Tulone. *Enhancing efficiency of Intrusion–tolerant coordination protocols via hash functions.* In Proc. of the 10th ACM Conf. Euro–Par 2004, pp. 587-595, Sept 04. An extended version can be found in Tech. Report, ISTI CNR, Pisa. Apr 03.
13. D. Tulone. *How efficiently and accurately can a process get the reference time?* Intl. Symp. on Distributed Computing, Brief announcement, pp. 25-32, Oct 03.
14. D. Tulone. *Ensuring causal consistency in Internet–based services with arbitrary failures.* In 6th IEEE Intl. Symp. on Autonomous Decentralized Systems, fast abstract, pp. 17-18, April 03.
15. R. Baldoni, C. Spaziani, S. Tucci–Piergiovanni, D. Tulone. *An implementation of causal memories using the writing semantic.* In Proc. of 6th Intl Conf. On Principles of Distributed Sys, pp. 41-50, Dec 02.

16. D. Malkhi, M. K. Reiter, D. Tulone, E. Ziskind. *Persistent objects in the Fleet system.* In Proc. of the 2nd IEEE Darpa Information Survivability Conference and Exposition, Vol. 2, pp. 1126-1137, Jun 01.
17. D. Tulone, C. Yap, C. Li. *Randomized zero testing of radical expressions and Elementary Geometry theorem proving.* In Proc. of Intl. Workshop on Automated Deduction in Geometry, Sept 00.

Other manuscripts

18. D. Tulone, S. Madden. *Time series forecasting for efficiently answering queries and detecting similarities in sensor networks.* Technical report, in preparation for journal submission.
19. J. Heikkonen, D. Tulone. *A hierarchical model-based framework for answering queries in very large sensor networks.* In preparation for journal submission.
20. D. Tulone. *An optimistic adaptable information dispersal and recovery scheme.* Manuscript, MIT, May 06.
21. D. Tulone. *On the design of an intrusion-tolerant distributed function.* Manuscript, MIT CSAIL, Mar 06.
22. D. Tulone. *Mechanisms for energy conservation in wireless sensor networks.* Ph.D. thesis, Department of Computer Science, University of Pisa, Dec 05.
23. D. Tulone. *Efficiency and intrusion-tolerance: reconcilable aspects of the same coin?* Ph.D. thesis proposal, Dept. of Computer Science, Univ. of Pisa. Mar 04.
24. D. Tulone, C. Yap. *Cookbook bounds for multi–term recursions.* Manuscript, New York Univ., Feb 98.
25. D. Tulone. *ETNA: Extensible Theorem Prover in NAtural deduction, in Set Theory.* M.S. thesis (tesi di laurea), Dept. of Mathematics, Univ. of Catania, Mar 94.

SOFTWARE PRODUCED

- Co-author of a 3-tier system to assist AT&T customers by connecting to different systems to retrieve information (Java at the client-side, C++ at the server-side, and Oracle), and a 3-tier web-based system using Java servlets at the client-side. These systems have been in production since March 1999.
- Author of the *Prover system* [3], a probabilistic automatic theorem prover, which is part of the *Core library*, a library designed for the exact geometric computation. It is downloadable at http://cs.nyu.edu/exact/core/prover. Deployed in March 1999.
- Co-author of the Fleet system, a middleware system that implements an intrusion–tolerant data repository for persistent shared objects [16]. Deployed to DARPA in September 2001.
- Author of a simulator for the SAF system [4]. May 2006.

INVITED TALKS

- *A secure and scalable digital time-stamping system for real-time applications.* ETH, Zurich. May 2007.
- *SAF: a Similarity-based Adaptable query Framework for sensor networks.* Univ.La Sapienza, Rome. April 2007.
- *Time series forecasting for efficiently answering queries and detecting similarities in sensor networks.* IBM Research Lab (Zurich), Politecnico di Milano, and Thomson Paris Lab. Jul 2006.
- *An energy-efficient monitoring system for wireless sensor networks.* Yahoo Research (Barcelona). Sept 2006.
- *Trade-offs between data accuracy and efficiency in wireless sensor networks.* CSAIL, MIT. Feb 2005.
- *Persistent objects in the Fleet system.* Univ. of Salerno, Univ. of Bologna, and Eurecom. Jun 2002.
- *The Principles behind the Fleet system.* Bell-Labs. May 2002.

COMPUTER SKILLS

- *Programming Languages:* Java, C, C++, Matlab.
- *Operating Systems:* Unix and Windows platforms.
- *Distributed Systems:* RMI, CORBA, EJB, JINI.
- *Network Standards:* 802.11.x, 802.15.x, WirelessHart, ISA100.11a.

REFERENCES AVAILABLE UPON REQUEST