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Research Objectives

To enhance the Quality of Service (QoS) in Wireless Network Protocols by
- developing scalable and energy efficient routing protocols
- developing optimal network layout for better QoS
- developing efficient and fair scheduling algorithms

To prevent cyber-attackers from acquiring or damaging personal or private data by
- using Software Defined Networking (SDN) as a robust Firewall
- enhancing privacy on Mobile phones
- developing framework for securing information flow in web applications
- developing techniques for preventing network pre-attacks

To improve the techniques used for sentiment analysis in Arabic and emotion recognition by
- developing the Arabic resources needed for sentiment analysis
- improving the accuracy and robustness of sentiment analysis systems in Arabic
- developing accurate emotion recognition algorithms and devices in natural settings

Career Synopsis

- **Research Activities:**
  - **25 refereed journal publications** in prestigious Journals such as **ACM Transactions**, **IEEE Transactions, IEEE Sensors, ComCom, JNCA, Computers & Security**, and **BMC Bioinformatics**.
  - **59 refereed conference publications** published in top IEEE conferences including **ICDM, IWCMC, NetSoft, Globecom, ICC, AINA, and WCNC.**
  - **Filed for 2 patent inventions** on context aware sensing
  - **18 research grants, including two major funds from Qatar Foundation in 2013 and 2018, for the amounts of $600,000 and $1,050,000 respectively.**
  - **Elected in September 2018** to serve as the **General Chair** of the *4th Workshop on Arabic Natural Language Processing (NLP)*, a highly respected research venue for work related to Arabic NLP.
  - **Thesis Advisor** for **12 MS** students at the American University of Beirut (AUB), and **Co-Advisor and/or Committee member** for **15 MS** and **2 Ph.D.** students at AUB.

- **Teaching Activities:**
  - **Introduced new courses**, such as CMPS 101 - Introduction to Computer Science, SECB 301 - Security Principles and Practice, SECB 351 - Access Control Models & Technologies, and SECB 430 - Secure Electronic Commerce.
  - **Revamped** several Computer Science courses at AUB including: CMPS 200 - Introduction to Programming, CMPS 212 - Intermediate Programming with Data Structures, CMPS 284 - Computer Networks, and CMPS 274/374 - Compiler Construction.
  - The average **Instructor Course Evaluations (ICE)** scores of all AUB courses taught is **4.1 out of 5.0**, well above the faculty and university averages.

- **Services**
  - Elected as department Chairperson, *Sep. 2013-ongoing*.
  - Elected as a member of the AUB Senate, *Sep. 2017-ongoing*.

- Elected as a member of the AUB Senate Committee for Faculty Affairs (SCFA), *Sep. 2017-ongoing*.
- AUB Senate Secretary, *Sep. 2018 – ongoing.*
- **Coordinator and curriculum developer** for the Tech for Food program funded by World Food Programme that aims to teach Syrian refugees and underserved Lebanese digital skills, *2016-ongoing*.
- **Main Organizer** for many national events and contests such as: **2017 ArabWIC** 5th Annual International conference on Arab Women in Computing, **VEX Robotics** Contest, the 5th and 6th **ACM** Lebanese Collegiate Programming Contest, and Computer Science for High School (**CS4HS**) tutorials.
- Initiated a **corporate sponsorship program** between the Computer Science department at AUB and local companies.
- AUB **Title IX officer**. Acquired Civil Rights Investigator Level Two certificate.

Education

- *Western Michigan University,* Michigan, USA
  Doctor of Philosophy in Computer Science, June 2006
  Dissertation Title: *A Distributed Hierarchical Energy-Efficient Scheme for Large Scale Mobile Ad Hoc Networks*.
- *Western Michigan University,* Michigan, USA
  Master of Science in Computer Science, June 2002.
- *American University of Beirut*, Lebanon.
  BS in Computer Science, June 2000.

Honors and Awards

- **Elected in September 2018** to serve as the **General Chair** of the *4th Workshop Arabic Natural Language Processing (NLP)*, a highly respected research venue for work related to Arabic NLP.
- **Invited to present a tutorial on internet security** at the 9th international Wireless Communication and Mobile Computing Conference - **IWCMC 2013** (http://iwcmc.org/2013/tutorials/)
- **2nd best paper award** in the IEEE International Conference on Electronics, Circuits, and Systems (**ICECS 2011**)
- **Invited by Google** to participate in the fourth Europe, Middle East and Africa (EMEA) Faculty Summit, Zurich, Switzerland, **2011**.
- Honorable mention for **Graduate Research and Creative Scholar** (2005)
- **Graduate Honor Roll Award** at WMU (2005).
- Recipient of the **Outstanding Graduate Student Award** (Ph.D. level) for two years in a row: 2004, 2005.
- Recipient of the **Excellence in Research Award** (Ph.D. level) for three years in a row: 2003, 2004, 2005.
- **Recipient** of the **Teaching Effectiveness Award (2002)** at Western Michigan University (WMU), USA.

Academic Positions

- *Associate Professor, Computer Science Department, American University of Beirut, Lebanon, Sept. 2014-present*

  Research Contributions: I conduct research in network protocols, cyber security, and machine learning (focusing on sentiment and emotion analysis). In rank, I have published breakthroughs in RFID anti-collision algorithms, securing web applications and securing Software-defined networking (SDN), and automating categorization of emotion and sentiment in written Arabic.

  Published 7 peer reviewed journal articles, all of which appeared in highly respected venues in the areas of networks, security, and machine learning: (1) Three in ACM Transactions on Asian and Low-Resource Language Information Processing (TALLIP), (2) one in ACM Transactions on Information Systems (TOIC), (3) one in Computers & Security, (4) one in Computer Communications, and (5) one in IEEE Transactions on Very Large Scale Integration Systems (TVLSI). Also published 27 peer reviewed conference articles in respected venues in the areas of networks, security, and machine learning, for instance, ACM SIGSEM, IEEE NetSoft, IEEE IWCMC, and WNLP workshop series. Received, as a lead PI, 5 research grants for a total amount of $75,000: $35,000 of which are from industry (Computers & Communication Technology SAL and International Labour Organization

(ILO)), $25,000 from AUB's Farouk Jabre Interfaculty Grants, and $15,000 from AUB's Research Board. Also received as a PI a grant from Qatar Foundation for the amount of $600,000. The number of citations increased in this period by around 800 citations, landing at 1194 citations, with an increasing trend as shown in this snapshot from Google Scholar (Captured on December 17, 2018):

Citations	1267	1017
h-index	20	17
i10-index	35	30
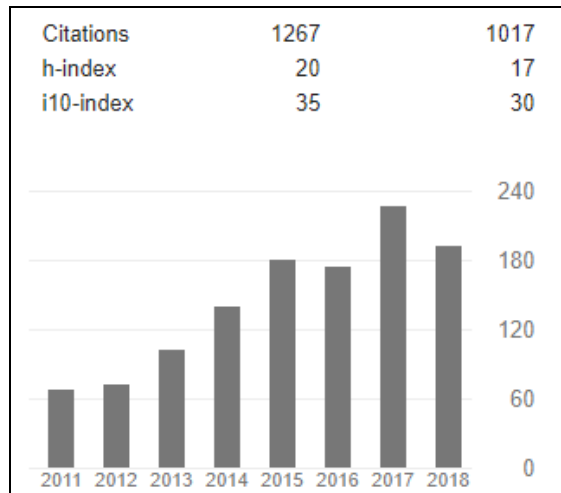
For RFID, we proposed a new distributed multi-channel anti-collision algorithm, which solves all the three types of RFID collisions. My personal contributions include the design of the actual communication protocol, and helping in the experimental setup.

For cyber security, I lead the work related on securing web applications. I suggested an easy to use and efficient approach to implement error free web applications. I also lead the work on SDN, and suggested a mechanism that transforms the SDN into one big firewall, while optimizing the burden on the data plane and achieving correctness.

For machine learning, I am currently leading a project that aims to detect the emotions of individuals based on data collected from the individual's mobile phone and from on-body sensors. The project is in collaboration with Dr. Fadi Maalouf, from the Division of Child and Adolescent Psychiatry at AUB Medical Center. The project is in its initial phases, but if successful will have a great impact on the way physiatrists evaluate the mental conditions of patients.

Also in Machine Learning, my main focus in rank was on sentiment analysis in Arabic. We developed and made public all the needed Arabic resources to perform sentiment analysis, which otherwise were non-existent. We also developed and published the highest performing algorithms for sentiment analysis, outperforming all existing approaches. **My personal contribution to this work is many folds**:
   (1) Leading the work on credibility analysis,
   (2) leading and in few cases co-leading the work on emotion recognition,
   (3) leading all the software architecture aspects of designing and conducting the experimental evaluations, which are among the most important aspects of the work, and
   (4) contributing to the development of the resources and the actual design of the machine learning algorithms.

Teaching and Supervision: Taught CMPS 200 - Introduction to Programming, CMPS 207 - Programming for Digital Arts, CMPS 212 - Intermediate Programming with Data Structures, and CMPS 299 - Software Graduation Project, where I received an average Instructor Course Evaluations (ICE) score of 4.1 out of 5.0, well above the faculty and university averages.

Graduated four MS students and co-advised 7 other MS students, all from Computer Science. I also co-advised two Ph.D. students from Electrical and Computer Engineering at AUB.

Department Chairperson and University Senator: Served as the Chairperson of the Computer Science department with many notable achievements such as, winning almost all computing related contests in Lebanon and competing very well internationally, increasing the department size to 373 students (243 before I took on this service) while notably increasing the admission score in order to get good students, quadrupling the graduate program (MS program), increasing the faculty size by one third, and collaborating closely with most departments within FAS and with all other faculties in AUB.

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Serving as a University Senate member since September 2017. Also elected during the same time to serve as a member of the Senate Committee for Faculty Affairs. Starting September 2018, I started serving as the Senate secretary. This is in addition to heading many departmental committees and being a member of many other committees in FAS and AUB.

- *Assistant Professor, Computer Science Department, American University of Beirut, Lebanon, Sept 2010-Sept 2014*

  Research Contributions: Published 9 journal articles in the areas of networks and security, all of which are refereed and in respected venues such as IEEE Sensors Journal and Journal of Network and Computer Applications (JNCA). Also published 14 peer reviewed conference articles in respected venues in the areas of networks and security, for instance, IEEE ICC, AINA, ISWTA, and IWCMC. Received 5 research grants, one of which was awarded by Qatar Foundation for the amount of $1,050,000 for the aim of developing resources and tools, and study new problems relating to the extraction of opinions from primarily Arabic text.

  In networking, specifically wireless networks (Sensor Networks, LTE, RFID, VANETs, and WiFi.), I developed:
  - distributed solutions to address the scalability and energy efficiency challenges in Mobile Ad Hoc Networks (MANETs), which resulted in doubling the network's lifetime is almost all scenarios.
  - boolean Satisfiability (SAT) solvers to solve the clustering optimization problem in MANETs.
  - new and advanced simulation tool for MANETs visualization.
  - efficient approaches to solving the sink placement problem in wireless sensor networks.
  - a novel uplink frequency domain scheduling algorithm in LTE that outperformed the state-of-the-art approaches and that takes into account network scalability, user mobility, and user QoS requirements
  - efficient algorithms to solve the reader collision problems in dense RFID environments. The main target performance metric is minimizing the identification delay, collision probabilities, and network overheads.

  In security, I developed accurate techniques for detecting & preventing popular network pre-attacks; specifically, I developed:
  - rule-based and machine learning techniques to detect normal, slow, and distributed port scanning activities
  - studies with critical evaluations and possible enhancements to the existing security measures in Cognitive Radio Networks, Smart Grid, and Transport Layer.

  Also worked on developing methods for energy aware computing. The key idea revolves around identifying and measuring the energy consumption of frequently used operations in the algorithm. Optimizing these operations that we call "kernels" leads to major impact on the overall computational efficiency.

  Teaching and Services: Taught CMPS 200 - Introduction to Programming, CMPS 207 - Programming for Digital Arts, CMPS 212 - Intermediate Programming with Data Structures, CMPS 284 - Computer Networks, CMPS 274/374 - Compiler Construction, and CMPS 299 - Software Graduation Project, where I received an average Instructor Course Evaluations (ICE) score of 4.06 out of 5.0, well above the faculty and university averages. Supervised 4 MS students, co-supervised 4 more MS students and one Ph.D. student with other professors.

  Started serving as the department chairperson since Sep. 2013.

- *Visiting Assistant Professor, Electrical & Computer Engineering Department, American University of Beirut, Lebanon, Jan 2010-Sept 2010*

  Worked on a project funded by Intel for the aim of developing energy aware algorithms with focus on compute intensive applications such as machine learning.

  Taught EECE 433 - Data Bases Management Systems, and EECE 450 - Computer Networks, where I received 4.3 and 4.1 Instructor Course Evaluations (ICE) score respectively, well above the faculty and university averages.

- *Assistant Professor, Information Security Department, College of Information Technology, UAE University, Aug 2006-Jan 2010*

  Research Contributions: Published 9 journal articles in the areas of networks and security, all of which are refereed and in respected venues such as IEEE Transactions on Vehicular Technology and Computer Communications. Also published 8 peer reviewed conference articles in respected venues in the areas of networks

and security, for instance, IEEE Globecom, ICC, and IWCMC. Received 7 research grants for a total amount of $150,000.

In networking, specifically wireless networks (Sensor Networks, LTE, RFID, VANETs, and WiFi.), I lead the work and developed:
- − distributed solutions to address the scalability and energy efficiency challenges in Mobile Ad Hoc Networks (MANETs), which resulted in doubling the network's lifetime is almost all scenarios.
- − new software framework (FW) that aims for quick development of intelligent applications with networked vehicles.
- − an optimal WiMAX deployment strategy. The main target performance metric is minimizing the number of WiMAX stations required, minimizing in-building signal losses, and minimizing the effect of mountains obstructions, while maximizing the coverage and number of users able to connect.
- − an algorithm that optimally assigns a particular frequency to each Access Point such that the throughput is maximized and the interference between Access Points is minimized.

In security, I lead the work and in few cases co-lead it to develop accurate techniques for detecting & preventing popular network pre-attacks, specifically developed:
- − a stateful ARP cache with fuzzy logic controller to detect ARP spoofing attacks, which are often used as part of other serious attacks such as Man-in-the-Middle (MiM) and Denial of Service (DoS).
- − two-factor authentication methods using mobile phones. Contributions include the implementation and testing of a mobile-based software token system that can replace existing hardware and computer-based software tokens. This work received high attention from the research community with 227 citations to date.

Also worked on developing a simple yet effective method to detect Protein-protein interaction (PPI) based on pairwise similarity and using only the primary structure of the protein, which lead to a prestigious publication in BMC Bioinformatics.

Teaching: Taught SECB 301 - Security Principles and Practice, SECB 351 - Access Control Models & Technologies, SECB 408 - Secure Mobile Code, SECB 405 - Security Protocols for the Internet and E-Commerce, SECB 430 - Secure Electronic Commerce

Research Grants

1. "*Optimized and Secured Demand Response Using Smart Meters and Blockchain for the Qatari Grid*" (PI), grant offered by **Qatar Foundation** for the amount of **$600,000**, December 2018. In this project, we address Smart Grid infrastructure and aim to develop an optimized demand side and demand response strategy while incorporating smart meter data and transformer loading condition. We also aim to develop a secured 2-way communication between smart meters and utilities using Blockchain technology and optimized outlier detection algorithms.
    - ▪ Lead Principal Investigator (LPI): Khaled Bashir Shaban, Computer Science and Engineering, Qatar University
    - ▪ Principal Investigator (PI): **Wassim El-Hajj**, Computer Science, AUB
    - ▪ Principal Investigator (PI): Hazem Hajj, Electrical Engineering, AUB
    - ▪ Principal Investigator (PI): Rabih Jabr, Electrical Engineering, AUB
    - ▪ Principal Investigator (PI): Ahmed Massoud, Qatar University (QU)
    - ▪ Principal Investigator (PI): Ayman El-Hag, University of Waterloo (UW)
    - ▪ Principal Investigator (PI): Ramadan El-Shatshat, University of Waterloo (UW)

2. "*Automated Emotion Recognition for Better Mental and Medical States of Being*" (PI), grant offered by **Farouk Jabre Interfaculty Grants** at the American University of Beirut for the amount of **$25,000, July 2018**. Since emotions play a central role in our lives as seen from different perspectives, the aim of this project is to build a large collection of resources for research and applications on emotion recognition, and to develop automated deep learning neural network models for emotion recognition.
    - ▪ Principal Investigator (PI): **Wassim El-Hajj**, Computer Science, AUB
    - ▪ Co- Principal Investigator (Co-PI): Fadi Maalouf, Child and Adolescent Psychiatry, Medical School
    - ▪ Co- Principal Investigator (Co-PI): Hazem Hajj, Electrical Engineering, AUB

3. "*ILO software/toolkit on Labour Force Surveys sampling designs*" (PI), grant offered by the **International Labour Organization (ILO)** for the amount of **$15,000**, **July 2018**. The aim of the project is to create a new state-of-the-art software/toolkit for Labour statistician for the objective of maximizing their productivity and reducing the labour survey errors. The software will include appropriate UI and UX on the front end and algorithms' optimization on the backend.

   - Principal Investigator (PI): **Wassim El-Hajj**, Computer Science, AUB

4. "*Mining for Credible Opinions in Arabic Blog Posts*" (PI), grant offered by the **American University of Beirut Research Board** (**URB**) for the amount of **$8,500**, **July 2016**. The aim of this project is to build a tool that automatically rates the credibility of Arabic blog posts in real-time; adopting the Merriam Webster credibility definition: *credibility is the quality of being believed or accepted as true, real or honest*. We focus on Arabic blog posts due to their recent popularity fueled by the recent uprisings in the Arab world, and due to the scarcity of tools for assessing credibility of Arabic blog posts.

   - Principal Investigator (PI): Wassim El-Hajj, Computer Science, AUB

5. "*White Space Management in Plants Industry 2D Piping Drawing*" (PI), one-year grant offered by **Computers & Communication Technology SAL - Offshore** (**CCT**), for the amount of **$20,000**, **July 2015**. In this project, we aim to build a tool for Oil/Gas Plants Industry that accepts as input, a 2D piping isometrics (extracted from 3D model representation) and produces a new cleanly annotated drawing with all annotations occupying the available white space without having any intersection. Annotations include pipes' dimensions, weld types/numbers, routing "offsets", comments, symbols to represent different fittings (valves, flanges, tees, instruments, supports, welds, etc.

   - Principal Investigator (PI): **Wassim El-Hajj**, Computer Science, AUB
   - Co- Principal Investigator (Co-PI): **Mohamad Jaber**, Computer Science, AUB

6. "*Efficient Detection of Information Leaks in Web Applications*" (PI), grant offered by the **American University of Beirut Research Board (URB)** for the amount of **$6,000**, **July 2014**. In this proposal, we propose a framework that enforces security-by-construction in web applications, where any violation in the data's confidentiality or integrity policies is reported at its source. Minimal developer effort is required, in a sense that the developer only needs to annotate database attributes by a security class.

   - Principal Investigator (PI): **Wassim El-Hajj**, Computer Science, AUB

7. "*Opinion Mining for Arabic with Models of Semantics and Credibility*" (PI), grant offered by **Qatar Foundation** for the amount of **$1,050,000, May 2013.** In this project, we aim to develop resources and tools, and study new problems relating to the extraction of opinions from primarily Arabic text.

   - Lead Principal Investigator (LPI): Hazem Hajj, Electrical Engineering, AUB
   - Principal Investigator (PI): **Wassim El-Hajj**, Computer Science, AUB
   - Lead Principal Investigator (LPI): Khaled Bashir Shaban, Computer Science and Engineering, Qatar University
   - Principal Investigator (PI): Nizar Habash, Center for Computational Learning Systems, Columbia University

8. "*Optimizing OLSR using Mobile Agents*" (PI), grant offered by the **American University of Beirut Research Board (URB)** for the amount of **$6,000**, **July 2013**. In this project, we propose an approach that uses mobile agents (MA) to maintain MANET topology information.

   - Principal Investigator (PI): **Wassim El-Hajj**, Computer Science, AUB

9. "*Slow-Distributed Port Scanning Detection*" (PI), grant offered by the **American University of Beirut Research Board** (**URB**) for the amount of **$5,200, June 2012**. In this project, we aim to provide a mechanism to detect and consequently prevent port scans that are both, slow and distributed. The real challenge is to develop an accurate approach that has low false positive and false negative alarms.

   - Principal Investigator (PI): **Wassim El-Hajj**, Computer Science, AUB

10. "*Google CS4HS 2012*" (PI), grant offered by **Google** for the amount of **$8,000** to promote Computer Science and Computational Thinking in high school and middle school curriculum. The proposal aims to gather a large group of high school teachers and train them on specific computer science principles and tools. In turn, the teachers will transmit this knowledge to their students throughout the academic year. A competition will then be held, in a fun

and encouraging atmosphere, between students to assess their newly acquired knowledge in computer science. **Event website**: http://www.cs.aub.edu.lb/blossoms/
- Principal Investigator (PI): **Wassim El-Hajj**, Computer Science, AUB
- Co- Principal Investigator (Co-PI): **George Turkiyyah**, Computer Science, AUB

11. "*Google's 2011 EMEA AndroidEDU grant*" (PI), grant offered by **Google** for an approximate amount of **$5,000**. Received **8 latest generation Samsung Galaxy S Plus** phones from Google to be used by Computer Science students and faculty for research and development.
- Principal Investigator (PI): **Wassim El-Hajj**, Computer Science, AUB

12. "*Arabic Semantic Analysis as a novel way to predict protein interaction*" (Co-PI), research grant funded by **Emirates Foundation** for the amount of **$55,000**, **March 2010**. In this project, we propose to develop a novel method to predict protein-protein interaction based on Arabic semantic analysis model. The semantic meaning will most likely give us a hint on how or why two proteins interact.
- Principal Investigator (PI): **Nazar Zaki**, College of IT, UAE University
- Co- Principal Investigator (Co-PI): **Wassim El-Hajj**, College of IT, UAE University

13. "*Protecting Communication Networks from Dangerous Subliminal Channels*" (PI), research grant funded by **Emirates Foundation** for the amount of **$55,000**, **March 2009**. The objective of this research/development project is to design and implement a system (Hardware and Software), called Covert Channel Detection System (CCDS), that will detect covert channels that carry secret messages within network traffic.
- Principal Investigator (PI): **Wassim El-Hajj**, College of IT, UAE University
- Co- Principal Investigator (Co-PI): **Zouheir Trabelsi**, College of IT, UAE University

14. "*Protecting UAE University Network from Port Scanning*" (PI), research grant funded by **UAE University** for the amount of **$6,000**, **November 2008**. In this research project, we investigate a novel approach, based on fuzzy logic, to detect port scanning attacks.
- Principal Investigator (PI): **Wassim El-Hajj**, College of IT, UAE University
- Co- Principal Investigator (Co-PI): **Zouheir Trabelsi**, College of IT, UAE University

15. "*Securing Simple Network Management Protocol (SNMP) through Usage Control Model*" (Co-PI), research grant funded by **UAE University** for the amount of **$5,500**, **November 2008**. In this research project, we investigate the shortcoming of the principle security facilities defined in SNMPv3: authentication, privacy, and access control. We also introduce new architecture that implements a new type of access control, called Usage Access control (U-Con), to control the access to the SNMP-based environment at: pre-connection, during connection, and post connection
- Principal Investigator (PI): **Ezedin Barka**, College of IT, UAE University
- Co- Principal Investigator (Co-PI): **Wassim El-Hajj**, College of IT, UAE University

16. "*An Efficient Hierarchical Scheme for MANETs that can Potentially Cover the whole UAE*" (Co-PI), research grant funded by **UAE University** for the amount of **$8,000**, **January 2007**. The objective of this project is to design an efficient large scale network, composed of cell phones, laptops, sensors, and other wireless devices, spanning a country like UAE.
- Principal Investigator (PI): **Mohsen Guizani**, College of IT, UAE University
- Co- Principal Investigator (Co-PI): **Wassim El-Hajj**, College of IT, UAE University

17. **"Using Fuzzy-Logic to Detect and Prevent Data Link Layer Attacks on UAEU Networks"** (PI), research grant funded by **UAE University** for the amount of **$8,000**, **January 2007**. In this research project, we propose a solution to the ARP poisoning problem based on extending the ARP protocol.
- Principal Investigator (PI): **Wassim El-Hajj**, College of IT, UAE University
- Co- Principal Investigator (Co-PI): **Zouheir Trabelsi**, College of IT, UAE University

18. "*Biometrics Fingerprint Time Attendance Recorders for UAEU Students*" (Co-PI), research grant funded by **UAE University** for the amount of **$5,500**, **January 2007**. In this project we design and implement a friendly GUI tool, an AntiSniffer, for detecting malicious sniffing hosts in the UAEU Wireless networks.
- Principal Investigator (PI): **Zouheir Trabelsi**, College of IT, UAE University
- Co- Principal Investigator (Co-PI): **Wassim El-Hajj**, College of IT, UAE University

Publications

- ## Patents

  1. Inventors: H. Hajj, **W. El-Hajj**, S. Eid *(S)*[*], M. Ben Saleh, Abdul Fattah Obeid, Syed Mansoor Qazim, "*System and Method for Multi-Device Continuum and Seamless Sensing Platform for Context Aware Analytics*," U.S. Provisional Patent Application Serial No.: 62/248,781. **Filing Date: October 30, 2015.**
     - **Personal Contribution: initiated the idea, proposed the platform architecture, and supervised the implementation.**

  2. Inventors: H. Hajj, **W. El-Hajj**, S. Eid *(S)*, M. Ben Saleh, Abdul Fattah Obeid, Syed Mansoor Qazim, "*Context-Aware Mobile Personalization System and Methods of Use*," U.S. Patent Application Serial No.: 62/115,399. **Filing Date: February 12, 2015, Published: August 8, 2016**.
     - **Personal Contribution: did all the software engineering work including design, data extraction, storage, privacy.**

- ## Journal Publications[†]

  1. Gilbert Badaro *(S)*, Ramy Baly *(S)*, Hazem Hajj, **Wassim El-Hajj**, Khaled B. Shaban, Nizar Habash, Ahmad Al-Salab *(PD)*, and Ali Hamdi, "*A Survey of Opinion Mining in Arabic: A Comprehensive System Perspective Covering Challenges and Advances in Tools, Resources, Models, Applications and Visualizations*," accepted in **ACM Transactions** on Asian and Low-Resource Language Information Processing (**TALLIP**), December 2018.
     - **Personal Contribution: was part of all aspects to the survey preparation.**

  2. Ramy Baly *(S)*, Hazem Hajj, Nizar Habash, Khaled B. Shaban, and **Wassim El-Hajj**, "*A Sentiment Treebank and Morphologically Enriched Recursive Deep Models for Effective Sentiment Analysis in Arabic*," **ACM Transactions** on Asian and Low-Resource Language Information Processing (**TALLIP**[‡]), Volume 16 Issue 4, Article No. 23, September 2017. (***Journal started in 2013– check footnote***)
     - **Personal Contribution: led the creation of the Arabic Sentiment Treebank (ARSENTB) and the experimental studies.**

  3. Ahmad Al-Sallab *(PD)*, Ramy Baly *(S)*, Hazem Hajj, Khaled B. Shaban, **Wassim El-Hajj**, and G. Badaro *(S)*, "*AROMA: A Recursive Deep Learning Model for Opinion Mining in Arabic as a Low Resource Language*," **ACM Transactions** on Asian and Low-Resource Language Information Processing (**TALLIP**[‡‡ above]), Volume 16 Issue 4, Article No. 25, September 2017. (***Journal started in 2013 – check footnote***)
     - **Personal Contribution: contributed to the design of the Recursive Auto Encoder (RAE) deep network, and led the evaluation and experimental studies.**

  4. Ramy Baly *(S)*, Roula Hobeica *(S)*, Hazem M. Hajj, **Wassim El-Hajj**, Khaled Bashir Shaban, and Ahmad Al Sallab, "*A Meta-Framework for Modeling the Human Reading Process in Sentiment Analysis*", **ACM Transactions on Information Systems (TOIC)**, Vol. 35, No. 1, Article 7, August 2016 *(**Impact Factor***: 2.312 – *Quartile 1)*
     - **Personal Contribution: major contributor to the idea, proposed the mapping between psychology theory and computer science algorithms, and contributed to the evaluation study.**

  5. **Wassim El-Hajj**, Ghassen Ben Brahim, Hazem Hajj, Haidar Safa, and Ralph Adaimy *(S)*, "*Security-by-Construction in Web Applications Development via Database Annotations*," **Computers & Security**, Volume 59, Pages 151–165, June 2016 *(**Impact Factor***: 2.650 – *Quartile 1)*
     - **Personal Contribution: initiated the idea, proposed the solution, and contributed to the experimental study**

  6. Haidar Safa, **Wassim El-Hajj**, Christine Meguerditchian *(S)*, "*A distributed multi-channel reader anti-collision algorithm for RFID environments*," **Computer Communications**, volume 64, 15 June 2015, Pages 44–56 *(**Impact Factor***: 2.613 – *Quartile 1)*

– **Personal Contribution: major contributor to the idea, the evaluation, and the experimental studies**

7. Hazem Hajj, **Wassim El-Hajj**, Mehiar Dabbagh *(S)*, and Tawfic Arabi, "*An Algorithm-Centric Energy Aware Design Methodology*," **IEEE Transactions** on Very Large Scale Integration Systems (**TVLSI**), 22.11 (2014): 2431-2435. **(Impact Factor:** *1.744 – Quartile 1***)**
   – **Personal Contribution: proposed the solution for identifying the "software kernels" and suggested heuristic alternatives to kernels with a tradeoff between energy consumption and accuracy.**

8. **Wassim El-Hajj**, Mustafa Al-Tamimi *(S)*, and Fadi Aloul, "*Real Traffic Logs Creation for Testing Intrusion Detection Systems*," **Wireless Communications and Mobile Computing** (**WCMC**), Wiley InterScience, 15(14), 1851-1864, October 2015. **(Impact Factor:** *0.869 – Quartile 2***)**
   – **Personal Contribution: initiated the idea, proposed the testbeds architecture, and led the Traffic Logs creations.**

9. Mehiar Dabbagh *(S)*, Hazem Hajj, **Wassim El-Hajj**, Mohammad Mansour, Ayman Kayssi, Ali Chehab, "*An Energy-Aware Design Methodology Based on Kernel Optimizations*," Int. J. Autonomous and Adaptive Communications Systems (**IJAACS**), Vol. 7, No. 3, 2014. **(Impact Factor:** *0.4 – Quartile 3***)**
   – **Personal Contribution: led the energy consumption analysis of the Back Propagation algorithm, and proposed alternative implementation for the kernels that has high energy consumption**

10. Syed Zahidi *(S)*, Fadi Aloul, Assim Sagahyroon, and **Wassim El-Hajj**, "*Optimizing Complex Cluster Formation in MANETs using SAT/ILP Techniques*," **IEEE Sensors Journal**, 13(6), 2400-2412, June 2013. **(Impact Factor:** *2.617 – Quartile 1***)**
   – **Personal Contribution: initiated the idea, led the Integer Linear Programming (ILP) formulation, and contributed to the experimental evaluation.**

11. Haidar Safa, **Wassim El-Hajj**, and Hanan Zoubian *(S)*, "*A Robust Topology Control Solution for the Sink Placement Problem in WSNs,*" Journal of Network and Computer Applications (**JNCA**), **Elsevier**, 39 (2014): 70-82. Available online: 3 May 2013, ISSN 1084-8045, http://dx.doi.org/10.1016/j.jnca.2013.04.009. **(Impact Factor:** *3.991 – Quartile 1***)**
   – **Personal Contribution: led the Integer Linear Programming (ILP) formulation, major contributor to the idea, and contributed to the experimental evaluation.**

12. M. Adel Serhani and **Wassim El-Hajj**, "*Movement-aware and QoS Driven Indoor Location and Mobile Service Discovery Framework,*" International Journal of Wireless and Mobile Computing 6.5 (2013): 481-500. **(Impact Factor:** *still computing, Quartile 2***)**
   – **Personal Contribution: formulated the problem, suggested the localization algorithm, and conducted the experimental studies and evaluations.**

13. Fadi Aloul, Abdul Rahman Al-Ali, Rami Al-Dalky *(S)*, Mamoun Al-Mardini *(S)* and **Wassim El-Hajj**, "*Smart Grid Security: Threats, Vulnerabilities and Solutions*," International Journal of Smart Grid and Clean Energy (**IJSGCE**), vol. 1, no. 1, September 2012: pp. 1–6. **(Impact Factor:** *still computing***)**
   – **Personal Contribution: identified the challenges for securing Smart Grids and proposed some solutions.**

14. **Wassim El-Hajj**, Haidar Safa, and Mohsen Guizani, "*Survey of Security Issues in Cognitive Radio Networks*," **Journal of Internet Technology**, vol. 12 no. 2, pp.181-198 (2011/3). **(Impact Factor:** *1.301 – Quartile 2***)**
   – **Personal Contribution: initiated the idea, conducted the study, and evaluated the cons and pros of each existing solution.**

15. **Wassim El-Hajj** (2012), "*The Most Recent SSL Security Attacks: Origins, Implementation, Evaluation, and Suggested Countermeasures,*" Security and Communication Networks (**SCN**), **Wiley,** vol. 5, Issue 1, pp. 113-124, January 2012. doi: 10.1002/sec.295. *Published online in Feb 2011.* **(Impact Factor:** *0.904 – Quartile 2***)**
   – **Personal Contribution: implemented the existing SSL attacks, evaluated them, and suggested countermeasures**

16. **Wassim El-Hajj**, Hazem Hajj, Zouheir Trabelsi, and Fadi Aloul (2011), "*Updating Snort with a Customized Controller to Thwart Port Scanning,*" Security and Communication Networks (**SCN**), **Wiley,** vol. 4, Issue 8, pp. 807–814. doi: 10.1002/sec.186 . *Published online in Jan 2010.* **(Impact Factor:** *0.904 – Quartile 2***)**
   – **Personal Contribution: created the fuzzy logic controller that aggregates traffic parameters for the purpose of detecting the possibility of network attacks, and integrated the controller in SNORT**

17. Zouheir Trabelsi and **Wassim El-Hajj**, "*On Investigating ARP Spoofing Security Solutions,*" **International Journal of Internet Protocol Technology (IJIPT)** SI Recent Advances on Network Attacks and Defenses, **Inderscience,** vol. 5, no. 1/2, pp. 92-100, 2010. **(Impact Factor: *0.85 – Quartile 4*)**
    – **Personal Contribution: major contributor to an algorithm that detects ARP spoofing, and led the experimental studies and evaluations.**

18. Hazem M. Hajj, **Wassim El-Hajj**, Karim Y. Kabalan, Mohamad M. El Dana *(S)*, Marwan Dakroub *(S)*, and Faysal Fawaz *(S)*, "*An Efficient Vehicle Communication Network Topology with an Extensible Framework,*" accepted in the **International Journal of Computing & Information Technology** (IJCIT), vol. 2, no. 2, pp. 237 – 250, 2010. **(Impact Factor: *0.53 – Quartile 3*)**
    – **Personal Contribution: proposed the network topology for efficient vehicle communications and suggested the distributed routing protocol**

19. **Wassim El-Hajj**, Ala Al-Fuqaha, Mohsen Guizani, and Hsiao-Hwa Chen, "*On Efficient Network Planning and Routing in Large Scale Manets,*" **IEEE Transactions on Vehicular Technology**, vol. 58, Issue 7, pages 3796-3801, Sept. 2009. **(Impact Factor: *4.432 – Quartile 1*)**
    – **Personal Contribution: suggested and implemented three efficient MANET protocols, one for network setup, one for maintenance, and one for routing.**

20. **Wassim El-Hajj**, Hazem M. Hajj, Ezedin Barka, Zaher Dawy, Omar El Hmaissy *(S)*, Dima Ghaddar *(S)*, and Youssef Aitour *(S)* (2009), "*Optimal WiMax Planning with Security Considerations,*" Security and Communication Networks **(SCN) SI on WiMax Security and Applications**, **Wiley**, 2009, vol. 2, Issue 5, pp. 401–412, doi: 10.1002/sec.128. **(Impact Factor: *0.904 – Quartile 2*)**
    – **Personal Contribution: suggested and implemented an iterative algorithm that minimizes the number of WiMax base station while maximizing the coverage, and adding an extra level of security.**

21. Nazar Zaki, Sanja L Lazarova-Molnar, **Wassim El-Hajj**, and Piers Campbell, *"Protein-protein interaction based on pairwise similarity,"* **BMC Bioinformatics** 10:150, 2009. **(Impact Factor: *3.114 – Quartile 1*)**.
    – **Personal Contribution: major contributor to an algorithm that efficiently compares proteins, and led the implementation and experimental studies.**

22. Fadi Aloul, Syed Zahidi, and **Wassim El-Hajj**, "*Multi Factor Authentication Using Mobile Phones,*" **International Journal of Mathematics and Computer Science**, vol. 4, no. 2, pages 65-80, 2009. **(Impact Factor: *0.6513 – Quartile 1*)**
    – **Personal Contribution: initiated the idea of two-factor authentication, and proposed two solutions to efficiently achieve secure authentication.**

23. **Wassim El-Hajj** and Hamed Alazemi, "*Optimal Frequency Assignment for IEEE 802.11 Wireless Networks,*" Wireless Communications and Mobile Computing **(WCMC)**, **Wiley**, vol. 9, Issue 1, January 2009, pages 131-141. Published Online: 28 Mar 2008. **(Impact Factor: *0.869 – Quartile 2*)**
    – **Personal Contribution: initiated the idea, formulated the problem mathematically, and proposed/implemented heuristic solutions.**

24. **Wassim El-Hajj**, Zouheir Trabelsi , and Dionysios Kountanis, "*Fast Distributed Dominating Set based Routing in Large Scale MANETs,*" **Computer Communications** (SI) on Network Coverage and Routing Schemes for Wireless Sensor Networks, **Elsevier**, vol. 30, Issues 14-15, 15 October 2007, pages 2880-2891. *(Impact Factor: 2.613 – Quartile 1)*
    – **Personal Contribution: initiated the idea, proposed a distributed algorithm to create a virtual backbone in MANET, and lead the implementation and experimental studies.**

25. **Wassim El-Hajj**, Dionysios Kountanis, Ala Al-Fuqaha, and Sghaier Guizani (2006) "*A Fuzzy-Based Virtual Backbone Routing for Large Scale MANETs,*" International Journal of Sensor Networks (**IJSNet**), **Inderscience**, vol. 4, no. 4, pages 250-259. **(Impact Factor: *0.635 – Quartile 3*)**
    – **Personal Contribution: initiated the idea, proposed the use of fuzzy logic to aggregate MANET node parameters, used the outcome to efficiently create a virtual backbone, and led the experimental studies.**

- **Refereed Conference Publications**

C1. A. Zeineddine *(S)* and **W. El-Hajj**, "*Stateful Distributed Firewall as a Service in SDN,*" IEEE International Conference on Network Softwarization (**IEEE NetSoft 2018**), 25-29 June 2018 – Montreal, Canada

- **Personal Contribution: initiated the idea, and proposed a mechanism to transform an SDN into a resilient firewall.**

C2. F. Makki *(S)*, **W. El-Hajj**, H. Safa, and A. Alhakim, "*A Module for Protecting Data Location Privacy on Mobile Devices*," 14th International Wireless Communications and Mobile Computing Conference (**IWCMC 2018**), Limassol, Cyprus, June 25-29, 2018.
- **Personal Contribution: initiated the idea, and proposed a solution for location privacy on mobile phones.**

C3. G. Badaro *(S)*, H. Jundi *(S)*, H. Hajj and **W. El-Hajj**, "*EmoWordNet: Automatic Expansion of Emotion Lexicon Using English WordNet*," Special Interest Group on Computational Semantics (**SIGSEM 2018**), New Orleans, USA, June 5-6 2018.
- **Personal Contribution: initiated the idea, contributed to the emotion lexicon generation, and supervised the implementation and experimental studies.**

C4. G. Badaro *(S)*, O. El Jundi *(S)*, A. Khaddaj *(S)*, A. Maarouf *(S)*, R. Kain *(S)*, H. Hajj and **W. El-Hajj**, "*EMA at SemEval-2018 Task 1: Emotion Mining for Arabic*," Proceedings of the 12th International Workshop on Semantic Evaluations (**SemEval 2018**), New Orleans, USA, June 5-6 2018.
- **Personal Contribution: led the design of the Word embeddings, which turned out to be one of the best features for emotion classification since they reduce semantic complexity, and also supervised the experimental studies.**

C5. G. Badaro *(S)*, H. Jundi *(S)*, H. Hajj, **W. El Hajj**, N. Habash, "*ArSEL: A Large Scale Arabic Sentiment and Emotion Lexicon*," The 3rd Workshop on Open-Source Arabic Corpora and Processing Tools (**OSACT 2018**), Miyazaki, Japan. 8th May 2018. Co-located with LREC 2018.
- **Personal Contribution: major contributor to the lexicon creation, and led the emotion regression and classification tasks which produced 30% improvements in the emotion classification accuracy.**

C6. R. Baly *(S)*, A. Khaddaj *(S)*, H. Hajj, **W. El-Hajj** and K. Shaban, "*ArSentD-LEV: A Multi-Topic Corpus for Target-based Sentiment Analysis in Arabic Levantine Tweets,*" The 3rd Workshop on Open-Source Arabic Corpora and Processing Tools (**OSACT 2018**), Miyazaki, Japan. 8th May 2018. Co-located with LREC 2018.
- **Personal Contribution: led the creation of a dataset composed of 4,000 Arabic tweets annotated for overall sentiment, sentiment target, sentiment expression, and tweet topic.**

C7. R. Baly *(S)*, G. Badaro *(S)*, A. Hamdi *(S)*, R. Moukalled *(S)*, R. Aoun *(S)*, G. El-Khoury *(S)*, A. El-Sallab *(PD)*, H. Hajj, N. Habash, K. Shaban, **W. El-Hajj**, "*OMAM at SemEval-2017 Task 4: Evaluation of English State-of-the-Art Sentiment Analysis Models for Arabic and a New Topic-based Model*," Proceedings of the 11th International Workshop on Semantic Evaluations (**SemEval 2017**), pages 594–601,Vancouver, Canada, August 3 - 4, 2017.
- **Personal Contribution: led the work on using English based sentiment algorithms on Arabic datasets.**

C8. J. Hatem *(S)*, H. Safa, and **W. El-Hajj**, "*Enhancing Routing Protocol for Low Power and Lossy Networks*," IEEE International Wireless Communications and Mobile Computing Conference (**IWCMC 2017**), Valencia, Spain, June 26-30, 2017.
- **Personal Contribution: contributed to the idea of updating the objective function in order to enhance network performance, and contributed to the simulation efforts.**

C9. M. O. Kayali *(S)*, Z. Shmeiss *(S)*, H. Safa, and **W. El-Hajj**, "Downlink Scheduling in LTE," IEEE International Wireless Communications and Mobile Computing Conference (**IWCMC 2017**), Valencia, Spain, June 26-30, 2017.
- **Personal Contribution: led the mathematical formulation efforts of existing techniques and of the proposed scheduling algorithm.**

C10. **W. El Hajj**, G. Ben Brahim, C. El-Hayek *(S)*, and H. Hajj, "*Feature Extraction and Large Activity-Set Recognition Using Mobile Phone Sensors*," International Data Science Conference (**iDSC 2017**), Salzburg, Austria, June 12-13 2017.
- **Personal Contribution: initiated the idea, and proposed 1-level classification approach that accurately classifies a large set of user activities using only mobile data.**

C11. R. El Ballouli *(S)*, **W. El-Hajj**, A. Ghandour *(S)*, S. Elbassuoni, H. Hajj and K. Shaban, "*CAT: Credibility Analysis of Arabic Content on Twitter*," The Third Arabic Natural Language Processing Workshop (**WANLP 2017**), co-located with EACL 2017, Valencia, Spain, April 3, 2017.
- **Personal Contribution: initiated the idea and led the work of classifying whether an Arabic tweet is credible or not.**

C12. R. Baly *(S)*, G. Badaro *(S)*, G. El-Khoury *(S)*, R. Moukalled *(S)*, R. Aoun *(S)*, H. Hajj, W. El-Hajj, N. Habash, and K. B. Shaban, "*A characterization study of arabic twitter data with a benchmarking for state-of-the-art opinion mining models*," The Third Arabic Natural Language Processing Workshop (**WANLP 2017**), co-located with EACL 2017, Valencia, Spain, April 3, 2017.
   – **Personal Contribution: contributed to the design and implementation of the Recursive Neural Tensor Network (RNTN) using Arabic datasets.**

C13. Nadine Ahmad *(S)*, Haidar Safa, **Wassim El-Hajj**, "*On the TAs reconfiguration problem in LTE networks*," IEEE International Wireless Communications and Mobile Computing Conference (**IWCMC 2016**), Paphos, Cyprus, September 5-9, 2016.
   – **Personal Contribution: led the mathematical formulation of the optimal tracking-areas configuration in LTE networks.**

C14. Khaled Dassouki *(S)*, Haidar Safa, Abbas Hijazi *(S)*, **Wassim El-Hajj**, "*A SIP delayed based mechanism for detecting VOIP flooding attacks*," (**IWCMC 2016**), Paphos, Cyprus, September 5-9, 2016.
   – **Personal Contribution: contributed to the solution and to the experimental setup and simulation.**

C15. Ayman Al Zaatari *(S)*, Rim El Ballouli *(S)*, Shady Elbassuoni, **Wassim El-Hajj**, Hazem M. Hajj, Khaled B. Shaban, Nizar Habash, Emad Yahya *(S)*, "*Arabic Corpora for Credibility Analysis*," Language Resources and Evaluation Conference (**LREC 2016**), Portorož (Slovenia), 23-28 May 2016.
   – **Personal Contribution: initiated the idea, and led the work of creating Arabic corpora (one from Twitter and one from Blogs) annotated for credibility, to support the research on credibility analysis.**

C16. L. Constantine *(S)*, G. Badaro *(S)*, H. Hajj, **W. El-Hajj**, L. Nachman, M. BenSaleh, and A. Obeid, "*A Framework for Emotion Recognition from Human Computer Interaction in Natural Setting*," 22nd ACM SIGKDD Conference on Knowledge Discovery and Data Mining (**KDD 2016**), Workshop on Issues of Sentiment Discovery and Opinion Mining (**WISDOM 2016**), San Francisco, August 14, 2016
   – **Personal Contribution: major contributor to the selection and validation of features that affect human emotions.**

C17. **Wassim El-Hajj**, Ghassen Ben Brahim, Haidar Safa, and Maha Akkari *(S)*, "*MOLSR: Mobile-Agent Based Optimized Link State Routing Protocol*," IEEE International Wireless Communications and Mobile Computing Conference (**IWCMC 2015**), Dubrovnik, Croatia, August 24-28, 2015.
   – **Personal Contribution: proposed the idea of replacing the MPR flooding protocol in OLSR, by a Mobile Agent that intelligently distributes messages across the network.**

C18. Haidar Safa, **Wassim El-Hajj**, Fatima K. Abu Salem, and Marwa Moutaweh *(S)*, "*Using K-Nearest Neighbor Algorithm to Reduce False Negatives in P2P Secure Routing Protocols*," IEEE International Wireless Communications and Mobile Computing Conference (**IWCMC 2015**), Dubrovnik, Croatia, August 24-28, 2015.
   – **Personal Contribution: major contributor to the algorithm that reduces false negatives in P2P networks, and contributor to the performance evaluation and simulation.**

C19. Fatima Makki *(S)*, **Wassim El-Hajj**, Abbas El-Hakim and Yves-Alexandre de Montjoye, "*Protecting the Privacy of Location Data using the openPDS/SafeAnswers Framework*," **NetMob 2015**, 7-10 April 2015, MIT Media Lab, Boston, USA.
   – **Personal Contribution: initiated the idea and led the work of creating a security module that protects mobile users from disclosing their location data to malicious third parties.**

C20. G. Badaro *(S)*, R. Baly *(S)*, R. Akel *(S)*, L. Fayad *(S)*, J. Khairallah *(S)*, H. Hajj, **W. El-Hajj**, and K. Bashir Shaban, "*A Light Lexicon-based Mobile Application for Sentiment Mining of Arabic Tweets*," In Proceedings of the Second Arabic Natural Language Processing Workshop (**ArabicNLP**), in conjunction with **ACL 2015**, Beijing, China, July 26-31, 2015.
   – **Personal Contribution: contributor to the creation of the lexicon and the experimental study.**

C21. A. Al Sallab *(PD)*, R. Baly *(S)*, G. Badaro *(S)*, H. Hajj, **W. El Hajj**, and K. B. Shaban, "*Deep Learning Models for Sentiment Analysis in Arabic*," In Proceedings of the Second Arabic Natural Language Processing Workshop (**ArabicNLP**), in conjunction with **ACL 2015**, Beijing, China, July 26-31, 2015.
   – **Personal Contribution: major contributed to the design of the deep learning models and the experimental study and evaluations.**

C22. R. Adaimy *(S)*, **W. El-Hajj**, G. Ben Brahim, H. Hajj, and H. Safa, "*A Framework for Secure Information Flow Analysis in Web Applications*," IEEE 29th International Conference on Advanced Information Networking and Applications, (**IEEE AINA 2015**), 24-27 March 2015, Gwangiu, South Korea
  – **Personal Contribution: initiated the idea and proposed a solution for securing web applications, which outperformed existing approaches while being easier to implement.**

C23. Shadi Shaheen *(S)*, **Wassim El-Hajj**, Hazem Hajj, and Shady Elbassuoni, "*Emotion Recognition from Text Based on Automatically Generated Rules*," In Proceedings of the 4th **IEEE ICDM** workshop on Sentiment Elicitation from Natural Text for Information Retrieval and Extraction (**SENTIRE 2014**), December 14, 2014, Shenzhen, China.
  – **Personal Contribution: initiated the idea and proposed a rule based solution for emotion recognition, which outperformed machine-learning algorithms and other rule-based approaches.**

C24. Haidar Safa, **Wassim El-Hajj**, and Marwa Moutaweh *(S)*, "*Trust Aware System for P2P Routing Protocols,*" IEEE 28th International Conference on Advanced Information Networking and Applications (**IEEE AINA 2014**), 2014, 13-16 May 2014, Victoria, Canada
  – **Personal Contribution: led the work on penetration testing to check how resilient the suggested protocol is, and contributed to the experimental study.**

C25. Gilbert Badaro *(S)*, Hazem Hajj, Ali Haddad *(S)*, **Wassim El-Hajj**, and Khaled Shaban, "*Recommender Systems Using Harmonic Analysis*," In Proceedings of the **IEEE ICDM** workshop on Social Multimedia Data Mining (**SMDM 2014**), December 14, 2014, Shenzhen, China.
  – **Personal Contribution: contributed to the new formulation for harmonic analysis with application to user-item matrix, and contributed to define all metrics used.**

C26. Gilbert Badaro *(S)*, Ramy Baly *(S)*, Hazem Hajj, Nizar Habash and **Wassim El-Hajj**, "*A Large Scale Arabic Sentiment Lexicon for Arabic Opinion Mining*," In Proceedings of the second **ACM EMNLP 2014** workshop on Arabic Natural Language Processing (**ANLP 2014**), October 25, 2014, Doha, Qatar.
  – **Personal Contribution: major contributor to the lexicon creation and evaluation.**

C27. Gilbert Badaro *(S)*, Hazem Hajj, Ali Haddad *(S)*, **Wassim El-Hajj**, and Khaled Shaban, "*A Multiresolution Approach to Recommender Systems*," In Proceedings of the **8th SIGKDD** workshop on Social Network Mining and Analysis (**SNA-KDD 2014**), August 24, 2014, New York City, United States.
  – **Personal Contribution: contributed to the solution that addresses sparse matrices in recommender systems.**

C28. Mustafa Al-Tamimi *(S)*, **Wassim El-Hajj**, and Fadi Aloul, "*Framework for Creating Realistic Port Scanning Benchmarks,*" IEEE International Wireless Communications and Mobile Computing Conference (**IWCMC 2013**), Cagliari-Sardinia, Italy, July 1-5, 2013.
  – **Personal Contribution: initiated the idea, created the realistic topologies, and led the experimental work that produced the benchmarks.**

C29. Gilbert Badaro *(S)*, Hazem Hajj, **Wassim El-Hajj**, and Lama Nachman, "*A Hybrid Approach with Collaborative Filtering for Recommender Systems,*" IEEE International Wireless Communications and Mobile Computing Conference (**IWCMC 2013**), Cagliari-Sardinia, Italy, July 1-5, 2013.
  – **Personal Contribution: led the experimental setup, and evaluations.**

C30. Haidar Safa, **Wassim El-Hajj**, and Kamal Tohme *(S)*, "*A QoS-Aware Uplink Scheduling Paradigm for LTE Networks*," 27th IEEE International Conference on Advanced Information Networking and Applications (**AINA 2013**), Spain, March 25-28, 2013.
  – **Personal Contribution: major contributor to the scheduling algorithm and the evaluation equations.**

C31. Chadi Trad *(S)*, Hazzem Hajj, **Wassim El-Hajj**, and Fatima Al-Jamil. "*Facial Action Unit and Emotion Recognition with Head Pose Variations*," Advanced Data Mining and Applications (**ADMA 2012**), Springer Berlin Heidelberg, Nanjing, China, December 15-18, 2012, pp 383-394
  – **Personal Contribution: major contributor to the idea of splitting the face into two parts then detect the emotions of each part, and finally fuse the results.**

C32. Syed Zahidi *(S)*, Fadi Aloul, Assim Sagahyroon, and **Wassim El-Hajj**, "*Using Sat & ILP Techniques to Solve Enhanced ILP Formulation of the Clustering Problem in MANETs,*" The 8th International Wireless Communications and Mobile Computing Conference (**IWCMC 2012**), August 27 - 31, 2012, Limassol, Cyprus
  – **Personal Contribution: led the mathematical formulations, proposed an enhanced formulation to the clustering problem in MANETs.**

C33. Syed Zahidi *(S)*, Fadi Aloul, Assim Sagahyroon, and **Wassim El-Hajj**, "*Solving the Clustering Problem in MANETS using SAT & ILP Techniques,*" 11th International Conference on Information Sciences, Signal Processing and their Applications (**ISSPA 2012**), 3-5 July 2012, Montreal, Quebec, Canada.
  – **Personal Contribution: led the mathematical formulations and testing.**

C34. Haidar Safa, **Wassim El-Hajj**, and Hanan Zoubian *(S)*, "*Particle Swarm Optimization Based Approach to Solve the Multiple Sink Placement Problem in WSNs,*" IEEE International Conference on Communications (**ICC 2012**), Ottawa, Canada, June 10-15, 2012
  – **Personal Contribution: formulated mathematically the multiple sink placement problem, solved the formulations, and contributed to the design of the heuristics algorithms.**

C35. Mehiar Dabbagh *(S)*, Hazem Hajj, and **Wassim El Hajj**, "*An Approach to Measuring Kernel Energy in Software Applications,*" International Conference on Energy Aware Computing (**ICEAC 2011**), Istanbul, Turkey   Nov 30– Dec 2, 2011
  – **Personal Contribution: major contributor to the "kernel" identifying, and contributed to the experimental study and evaluations.**

C36. Mehiar Dabbagh *(S)*, Ali Ghandour *(S)*, Kassem Fawaz *(S)*, **Wassim El Hajj**, and Hazem Hajj, "*Slow Port Scanning Detection,*" International Conference on Information Assurance and Security 2011 (**IAS 2011**), Malacca, Malaysia, 5-8 December 2011.
  – **Personal Contribution: initiated the idea and proposed solutions for detecting clever port scanning attacks.**

C37. Roula Hobeica *(S)*, Hazem Hajj, and **Wassim El-Hajj**, "*Machine Reading for Notion-Based Sentiment Mining,*" IEEE International Conference on Data Mining (**ICDM 2011**) SENTIRE, Vancouver, Canada, December 11-14, 2011.
  – **Personal Contribution: main contributor to the idea of automating human reading and applying it successfully to sentiment analysis.**

C38. Christine Meguerditchian *(S)*, Haidar Safa, and **Wassim El-Hajj**, "*New Reader Anti-collision Algorithm for Dense RFID Environments,*" IEEE International Conference on Electronics, Circuits, and Systems (**ICECS 2011**), Beirut, Lebanon, December 11-14, 2011. (*2nd best paper award)*
  – **Personal Contribution: led the experimental setup, experiments, and evaluations.**

C39. Noor Abbani *(S)*, Mohamad Jomaa *(S)*, Takwa Tarhini *(S)*, Hassan Artail, and **Wassim El-Hajj**, "*Managing Social Networks in Vehicular Networks Using Trust Rules,*" 2011 IEEE Symposium on Wireless Technology & Applications (**ISWTA 2011**), 25- 28 September 201, Langkawi, Malaysia.
  – **Personal Contribution: contributed to the mathematical analysis and the design of trust rules.**

C40. Mehiar Dabbagh *(S)*, Hazem Hajj, Ali Chehab, **Wassim El-Hajj**, Ayman Kayssi, and Mohammad Mansour, "*A Design Methodology for Energy Aware Neural Networks,*" The 7th International Wireless Communications and Mobile Computing Conference—(**IWCMC 2011**), July 4 - 8, 2011, Istanbul, Turkey.
  – **Personal Contribution: led the energy consumption analysis of the Back Propagation algorithm, and proposed alternative implementation for the kernels that has high energy consumption**

C41. Nazar Zaki and **Wassim El-Hajj**, "*Predicting Membrane Proteins Type Using Inter-domain Linker Knowledge,*" 2010 International Conference on Bioinformatics and Computational Biology (**BIOCOMP 2010**), July 12-15, 2010, 209-214, Las Vegas, USA.
  – **Personal Contribution: created and implemented protein-matching algorithm that is computationally very efficient outperforming existing algorithms.**

C42. Hazem M. Hajj, **Wassim El-Hajj**, Mohamad El Dana *(S)*, Marwan Dakroub *(S)*, Faysal Fawaz *(S)*,"*An Extensible Software Framework for Building Vehicle to Vehicle Applications,*" International Wireless Communications and Mobile Computing Conference (**IWCMC 2010**), Caen, France, June 28 - July 2, 2010.

– **Personal Contribution: led the proposition of a platform, integrated with AUTOSAR, to enable the development of new applications for intelligent vehicles**

C43. Zouheir Trabelsi and **Wassim El-Hajj**, "*ARP Spoofing: A Comparative Study for Education Purposes,*" Information Security Curriculum Development Conference (**InfoSecCD 2009**), Kennesaw, Georgia, September 25-26 2009.
– **Personal Contribution: conducted actual ARP attacks on test networks while bypassing well-known software and hardware IDS's, then presenting the study for educational purposes.**

C44. **Wassim El-Hajj**, Hazem Hajj, and Zouheir Trabelsi, "*On Fault Tolerant Ad Hoc Network Design,*" International Wireless Communications and Mobile Computing Conference (**IWCMC 2009**), Leipzig, Germany, 21-24 June 2009.
– **Personal Contribution: initiated the idea, proposed a distributed routing protocol, and created the mathematical metrics, which can be used for evaluating similar protocols.**

C45. Syed Zahidi *(S)*, Fadi Aloul, and **Wassim El-Hajj**, "*Two Factor Authentication Using Mobile Phones*," The 7th ACS/IEEE International Conference on Computer Systems and Applications (**AICCSA 2009**), Rabat, Morocco, May 10-13, 2009.
– **Personal Contribution: initiated the idea of two-factor authentication, and proposed two solutions to efficiently achieve secure authentication.**

C46. **Wassim El-Hajj**, Fadi Aloul, Zouheir Trabelsi, and Nazar Zaki, "*On Detecting Port Scanning using Fuzzy Based Intrusion Detection System,*" International Wireless Communications and Mobile Computing Conference (**IWCMC 2008**), Crete Island, Greece, August 6-8, 2008.
– **Personal Contribution: initiated the idea, created a fuzzy logic controller to detect port scanning attacks, and integrated the controller in Snort.**

C47. Lilia Frikha *(S)*, Zouheir Trabelsi, and **Wassim El-Hajj**, "*Implementation of a Covert Channel in the 802.11 Header,*" International Wireless Communications and Mobile Computing Conference (**IWCMC 2008**), Crete Island, Greece, August 6-8, 2008.
– **Personal Contribution: major contributor to implementing a covert channel at the data link layer.**

C48. **Wassim El-Hajj** and Zouheir Trabelsi, "*Using a Fuzzy Logic Controller to Thwart Data Link Layer Attacks in Ethernet Networks,*" Proc. of IEEE Wireless Communication and Networking Conference (**WCNC'07**), Hong Kong, China, 11-15 March 2007, pages 2547-2552.
– **Personal Contribution: initiated the idea, and created a fuzzy logic controller to detect and prevent ARP attacks.**

C49. Zouheir Trabelsi and **Wassim El-Hajj**, "*Preventing ARP Attacks using a Fuzzy-Based Stateful ARP Cache,*" Proc. of IEEE International Conference on Communications (**ICC 2007**), Glasgow, Scotland, June 24-28, 2007.
– **Personal Contribution: major contributor to the idea of using statefull ARP cache, as opposed to stateless ARP cache in order to detect ARP attacks.**

C50. **Wasim El-Hajj** and Mohsen Guizani, "*A Fast Distributed and Efficient Virtual Backbone Election in Large Scale MANETs,*" Proc. of **IEEE Globecom** Conference, San Francisco, California, USA, 27 November-1 December 2006, pages 1-6.
– **Personal Contribution: initiated the idea, proposed a distributed and efficient algorithm to find the connected dominating set in wireless ad hoc networks. The dominating set will then act as the network backbone.**

C51. Loay Abusalah *(S)*, Ashfaq A. Khokhar *(S)*, Ghassen Ben Brahim, and **Wassim El-Hajj**, "*TARP: Trust-Aware Routing Protocol,*" International Wireless Communications and Mobile Computing Conference (**IWCMC 2006**), Vancouver, British Columbia, Canada, July 3-6, 2006, pages 135-140.
– **Personal Contribution: major contributor to the idea of creating a network-route based on the trust values across the route. Also contributed to the simulations.**

C52. **Wasim El-Hajj** *(S)*, Dionysios Kountanis, Ala Al-Fuqaha, and Hani Harbi *(S)*, "*Optimal Hierarchical Energy Efficient Design for MANETs,*" International Wireless Communications and Mobile Computing Conference (**IWCMC 2006**), Vancouver, British Columbia, Canada, July 3-6, , 2006, pages 287-292.
– **Personal Contribution: initiated the idea and proposed mathematical formulations to the flat network and hierarchical network in MANETs.**

C53. **Wasim El-Hajj** *(S)*, Dionysios Kountanis, Ala Al-Fuqaha, and Mohsen Guizani, "*A fuzzy-based Hierarchical Energy Efficient Routing Protocol for Large Scale Mobile Ad Hoc Networks (FEER),*" Proc. of IEEE International Conference on Communications (**ICC 2006**), Istanbul, Turkey, June 10-15, 2006.
   – **Personal Contribution: initiated the idea and proposed a fuzzy-based hierarchical energy efficient routing scheme for large scale MANETs that aims to maximize the network's lifetime.**

C54. **Wasim El-Hajj** *(S)*, Ghassen Ben Brahim *(S)*, Chandra Achalla *(S)*, and Dionysios Kountanis, "*A New Algorithm That Improves Network Performance by Maximizing The Number Of Disjoint Paths,*" **Congressus Numerantium**, vol. 177, pp 15-24, March 7-11, 2005.
   – **Personal Contribution: initiated the idea and created an algorithm that distributes the routing load over disjoints paths to enhance performance.**

C55. Dionysios Kountanis, Vatsal S. Gandhi *(S)*, **Wasim El-Hajj** *(S)*, and Ghassen Ben Brahim *(S)*, "*A Network Topology With Efficient Balanced Routing,*" **Congressus Numerantium**, vol. 177, pp 201-215, March 7-11, 2005.
   – **Personal Contribution: major contributor to a topology setup that achieves balanced routing**

C56. **Wasim El-Hajj** *(S)*, Shujun Li *(S)*, Elise De Doncker, and Karlis Kaugars, "*Data Format Support for Parallel Numerical Integration,*" Proc. of Parallel and Distributed Computing and Systems (**PDCS 2004**), MIT Cambridge, USA November 9-11 2004, pp. 737-742.
   – **Personal Contribution: developed a new interface using XML for the parallel numerical integration package PARINT, in addition to developing the data manipulation and storage mechanism.**

C57. **Wasim El-Hajj** *(S)*, Dionysios Kountanis, and Anupama Raju *(S)*, "*Network Congestion Measurement and Control,*" **Congressus Numerantium**, vol. 171, pp 105-122, March 8-12, 2004.
   – **Personal Contribution: theoretically measuring the network congestion and proving that choosing an optimal route that minimizes congestion is NP-Hard.**

C58. Anupama Raju *(S)*, **Wasim El-Hajj** *(S)*, and Dionysios Kountanis, "*Computational Complexity of k-stratified Graph Construction,*" **Congressus Numerantium**, vol. 171, pp 207-222, March 8-12, 2004.
   – **Personal Contribution: major contributor to evaluating the computational complexity of k-stratified graph construction.**

C59. Dionysios Kountanis, Vatsal S. Gandhi *(S)*, **Wasim El-Hajj**, and Anupama Raju *(S)*, "*Minimum Steiner Tree Approximation using Binary Image Skeletons,*" **Congressus Numerantium**, vol. 168, pp 3-11, March 8-12, 2004.
   – **Personal Contribution: proposed the approximation algorithm for MRST based on the skeleton of a binary image, and contributed to the complexity analysis.**

- **Refereed Book Chapter's contribution**

1. Nazar Zaki, **Wassim El-Hajj**, Hisham Kamel, Fadi Sibai, "*STRIKE: a protein-protein interaction classification approach*," in Software Tools and Algorithms for Biological Systems, in the book series: Advances in Experimental Medicine and Biology (AEMB), Springer, 2010, 8 pages. (15% acceptance rate).
   – **Personal Contribution: major contributor to the protein-protein similarity algorithms.**

2. Authored a telecommunication chapter entitled "*Transmission Media*" in a book entitled "Computer Networks and Data Communications with the Internet" by Prof. Mohsen Guizani published by John Wiley and Sons Ltd on September 30, 2005.

Services to AUB and Community

- **University/Department**
  - Elected to serve as the **Computer Science Department Chair** at AUB starting *Sep. 2013-ongoing*
  - Elected as a member of the AUB Senate, *September 2017-ongoing*.
  - Elected as a member of the AUB Senate Committee for Faculty Affairs (SCFA), *Sep. 2017-ongoing*.
  - Chair of the department's assessment committee, *September 2013-ongoing*
  - Member in the AUB-wide academic assessment committee. *2017-2018*.
  - **Main organizer** of the **2017 ArabWIC** 5th Annual International conference on Arab Women in Computing,

- **Main Organizer** of the National VEX Robotics Contest. *March 2016*. https://www.aub.edu.lb/fas/fas_home/Pages/news-vex-robotics-competition-march2016.aspx
- Initiated a **corporate sponsorship program** between the Computer Science department at AUB and local companies. *2016*
- **Main Organizer** of a three-days workshop on "Computer Modeling and Simulation" held at AUB in *January 2016*
- Main Organizer of a three-days workshop on "Enterprise Architecture" held at AUB in *January 2016*
- Main Organizer of a three-days workshop on "Project Management" held at AUB in *August 2016*
- Main Organizer of a seminar series entitled "The Practical Challenges of Managing Big Data in the Cloud" held at AUB in *November 2016*
- Main Organizer of the 5th and 6th ACM Lebanese Collegiate Programming Contest (LCPC 2013: http://www.cs.aub.edu.lb/lcpc13/ and LCPC 2014: http://www.cs.aub.edu.lb/lcpc14/)
- **Member** of the Computer Science Department **Self-Study Committee** at AUB, *2012-13.*
- **Member** of the university wide **General Education Committee** at AUB, *2012 - 2013.*
- **Chair** of the **Book Adoption Committee** at the Computer Science Department, American University of Beirut, *2010 - 2013.*
- Freshman and Computer Science student **advisor** at AUB, 2011 - ongoing
- **Member** of the **Undergraduate and Academic Committee** at the Electrical and Computer Engineering Department, American University of Beirut, *2010*.
- **Member** of various committees at the college of IT, UAE Universities including: **Outreach Committee**, **Honor Committee**, and **Student Link Committee**, *2006 – 2009*.
- **Lead programming coach** for 15 Computer Science students at AUB to participate in the Local, Regional, and International ACM Collegiate Programming Contest.
- **Lead programming coach** for three teams in UAE University that participated in the UAE National Programming Contest 2008 (NPC'08).
- **Lead organizer** in the UAE National Programming Contest 2008 (NPC'08).

- **Community**
  - **Coordinator and curriculum developer** for the Tech for Food program funded by World Food Programme that aims to teach Syrian refugees and underserved Lebanese digital skills *2016-ongoing*.
  - **Design and development of Future Developer Summer Program for students with ages ranging from 10 to 17 years (2016, 2017, and 2018) -** conducted REP-AUB.
  - **Curriculum development for the Faculty of Information & Communication Technology at MUDUN University (2016) -** conducted REP-AUB.
  - **Design and development of Certification Programs for Building Modern Business Applications (2015) -** conducted REP-AUB.
  - **Assessment of the Computer Science department and the Humanities and Social Science electives at Rafic Hariri University, Lebanon (2014) -** conducted REP-AUB.
  - **Computer Science curriculum development for the American University of Abu Dhabi, UAE (2013) -** conducted REP-AUB.
  - **Main Organizer** of the Computer Science for High School (**CS4HS**) workshops conducted in AUB on December 1 and 8, *2012* (http://www.cs.aub.edu.lb/blossoms/).

- **Conference Organization**
  - **Program Chair** of The Third Arabic Natural Language Processing Workshop (**WANLP-2017**) co-located with EACL 2017, Valencia, Spain. https://sites.google.com/a/nyu.edu/wanlp2017/
  - **Co-Chair of the Wireless Sensor Networks Technical Track** in the fourth International Conference on Energy Aware Computing (**ICEAC 2013**).
  - **Publication Chair** in the 3rd International Conference on Communications and Information Technology (**ICCIT 2013**), Beirut, Lebanon 19-21 June, 2013
  - **Publication Chair** in the third International Conference on Energy Aware Computing (**ICEAC 2012**)
  - **Co-chair** of a workshop entitled "*High Performance and Energy-Aware Solutions with Data Mining and Wireless/Mobile Applications*" in conjunction with the 7th international Wireless Communication and Mobile Computing Conference (**IWCMC – 2011**)
  - **Co-Chair** of the *Computing Systems track* in the 6th International Conference on Innovations in Information Technology (**Innovations'09**).

- **WEB & IT Chair** in the fourth International Conference on Innovations in Information Technology (**Innovations'07**).

- **Technical Program Committee (TPC) in** WANLP, ICEAC, IWCMC, ISWTA, IEEE WCNC, and WiMAX Technology Workshop.

- **Reviewer** of research proposals submitted to Lebanese National Council of Scientific Research (NCSR), American University of Beirut, University Research Board.

- **Reviewer** of technical papers for IEEE Transactions on Wireless Communications, IEEE Communications Magazine, International Journal of Vehicular Technology, IEEE Wireless Communication, Security and Communication Networks Journal, Information Sciences, Wireless Communications and Mobile Computing Journal, Journal of Computer Systems, Networks, and Communications, IEEE INFOCOM, ICC - International Communications Conference, IEEE Globecom, IEEE WirelessCOM, WANLP, IWCMC, ICCIT, SIECP, IEEE Canadian Conference on Electrical and Computer Engineering, Optical Networking and wireless communication symposium.

- **President of Upsilon Pi Epsilon (UPE)**, the International Honor Society for the Computing Sciences, at Western Michigan University.

- **IEEE Senior Member** and **ACM Senior Member**.

Industry Experience

- **Western Michigan University (WMU):** January 2001 – July 2006:
  Research Doctorate Associate: August 2002 – July 2006:
  - ➢ **Distributed Language design and implementation (BOEING research project)**: This project consists of the design, analysis, and implementation using C++ of a user friendly language (Predicate Constraint Language (PCL)), which interacts with a proprietary database and uses artificial intelligence tools and procedures. In this project, my task consists of: the design of the grammar using BNF (Backus Naur Form), language types design and implementation, database design and implementation, grammar implementation and integration using **LEX** and **YACC**, and testing the grammar as well as performing performance analysis. PCL is currently being used by Boeing R&D department.

  - ➢ **Computer Networks & Telecommunications Lab** setup: Designing, installing, and configuring the telecommunication Lab equipment at WMU. The Computer Networks & Telecommunications lab uses a variety of Cisco **firewalls**, Cisco **routers**, Cisco Aironet **Access Points**, **Hubs**, and **Switches** including: Cisco PIX 515E/501 firewalls, Cisco 1760 and 2620 series routers, Cisco Aironet 1300 Wireless Access Points, Cisco FastHub 424, and Cisco Catalyst 1900 switches. Configuring the Lab equipment was done using IOS commands and Cisco ConfigMaker.

  - ➢ **Trust Aware Routing Protocols (TARP)** design: a suite of scalable secure protocols for unicast, multicast and broadcast communication primitives providing "secure" on-demand **wireless ad-hoc routing** service from a source to a destination with desired confidence level.

  - ➢ **ParInt** research project: Team member; Design and implementation of an effective interface for ParInt. ParInt is a software package that solves integration problems numerically. It is implemented in a **distributed environment** composed of a cluster of 64 processors operating in parallel. A library called MPI is used to run the ParInt code on many clusters (distributed memory). My task consisted of designing a user friendly interface using XML to facilitate running the ParInt software. Efficient C functions were written to parse and extract the needed information from the XML files.

- **Ten Strategic Consulting Co.**: June 2001 – August 2001:
  - ▪ Development of a **management information system**. In this project, I developed a system that analyses customer behavior and rates them according to many factors using complex equations. Security was added on top of the system to prevent duplication and misuse of the product.

- **American University of Beirut (AUB):** January 1998 – July 2000:
  - Network Lab administrator.

Software and Hardware Expertise

- **Software**:
  - Mobile Development (Android, iOS, Windows)
  - Programming Languages & Frameworks: .NET Framework, C, C++, JAVA, Python, VB, HTML, CSS, ASP, JavaScript, JQuery, Web Services and Service Oriented Architectures.
  - Network Programming: Socket Programming.
  - Networking Protocols: TCP/IP, IEEE 802.11, WiFi, and WiMax.
  - Networks*:* UNIX, TCP/IP, VPN configuration.
  - Network Security Protocols: SSH, SSL, Kerberos, ARP, IPSEC, SET, PGP.
  - Performance Evaluation of Telecommunication Systems: NS3, OPNET, LP solver, MATLAB, EXCEL optimization tools.
  - Operating Systems*:* UNIX (HP, Solaris, AIX), Linux, DOS, Windows NT Server and Workstation.
  - Database Management Systems: Oracle, Microsoft Access.
  - Compiler Tools: Lex, Bison, and Yacc.
  - Parallel Computations: MPI (for distributed memory), and CILK (for shred memory).

- **Hardware**:
  - MICA2/DOT Professional Kit: MOTE-KIT5040 Wireless Sensor Network Kit; a sensor kit used for Monitoring Applications.
  - Cisco equipment: Cisco PIX 515E/501 firewalls, Cisco Aironet 1300 Wireless Access Points, Cisco FastHub 424 hub, Cisco Catalyst 1900 switches, and Cisco 1760 and 2620 series routers.