PROGRAM on
Q*uantum Computing based* ***I****ntegrative* ***C****omplex* ***N****etworks/Systems (QICN),*

As the answer to the NSF solicitation
https://new.nsf.gov/funding/opportunities/expanding-capacity-quantum-information-science
and the initiative of the provost's office the program was developed with the objective of enhancing WPI's competitiveness in the field of quantum computing. The program has three segments.
1. ***S****trategies/Program in the* ***E****ducation (SoE)*
2. ***S****trategy/Program in* ***R****esearch segment (SoR) and*
3. ***S****trategy on Program* ***I****mplementation: (SoI)*

The program will be implemented in corresponding departments and coordinated from the provost's office by the program director professor Savo Glisic and advisory committee composed of the heads of the participating departments (or delegated representatives).

By the year 2030, already well elaborated, thirteen new courses and six research groups will be established. Already prepared, four books and series of survey/research papers will be published to enhance WPI's creditentials when applying for NSF and industrial project funding.

SoE -The establishment of each individual course should be handled in the WPI standard way, initiated in a given academic department and then spread over to other departments of interest. The Strategy (SoE) is designed to ensure coordinated and carefully synchronized evolution of WPI that will maximally enhance the competitiveness of WPI in education and research on Quantum Computing based integrative complex projects in the future as promoted by NSF.
In addition to the program director there is a list of the people that could help with the procedure in promoting and establishing the courses and provide active and constructive contributions to the content of the courses.
The initial draft of the material for these courses is ready (listed below). The printout of part of this material is available in provost's office. Two courses (in red) are already in the process of approval.

SoR -The ***S****trategy in* ***R****esearch segment (SoR) is elaborated within 6 research reports prepared in the format of survey papers to be further edited with the departments and submitted for publication.*

SoI -The ***S****trategy on Program* ***I****mplementation: The program will be implemented in corresponding departments and coordinated from the provost's office by the program director professor Savo Glisic and advisory committee composed of the heads of the participating departments (or delegated representatives).*

COURSES
Course 8 _ Quantum Error Correcting Coding
Course 7.5 Qubit Physics
Course 7.4 Quantum Channel Modelling and Measurements
Course 7.3_Quantum Transceivers Design

Course 7.2 Quantum Logic Gate Design (Savo, Aravind Padmanabhan P.K. Physics)
Course 7.1: Continuous Variable QC in Complex Networks
course 6.2_Quantum Machine Learning
course 6.1_Quantum Search Algorithms and Quantum Optimization
course 5_ Quantum vs Post-Quantum Security in Complex networks
course 4 Neuroscience and QC in Complex Networks
course 3 QC in Chemistry & Biology: Complex networks
course 2 QC Applications in Complex Networks
course 1 Complex Networks Optimization

MATERAL developed so far_____

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[2] Savo Glisic, IMPLEMENTATION ASPECTS of Quantum Computing, GC series: 7G Wireless Networks, report:310719492, http://www.ins-netgroup.com/wp-content/uploads/2022/04/5.pdf
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[12] S. Glisic, Wireless Quantum Networks: Volume 2, https://www.ins-netgroup.com/uncategorized/quantum-computing-in-complex-networks-volume-2/
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[15] S. Glisic, WIRELESS QUANTUM NETWORKS: Intelligent Continuous Variable Technology https://www.ins-netgroup.com/uncategorized/wireless-quantum-networks-intelligent-continuous-variable-technology/
[16] S. Glisic, Quantum Channel Information Theory
[17] S. Glisic, Quantum Decision Theory
[18] S. Glisic, Quantum Internet
[19] S. Glisic, Quantum Machine Learning
[20] S. Glisic, Quantum Search Algorithms
[21] S. Glisic, Fundamentals of Quantum Communications
[22] S. Glisic, Quantum Network on Graph
[23] S. Glisic, Quantum Computing in Wireless Networks
[24] S. Glisic, Quantum Error Correction
[25] S. Glisic, QC Optimization
[26] S. Glisic, Artificial Neural Networks
[27] S. Glisic, Learning Equilibria and Games
[28] S. Glisic, Machine Learning Algorithms
[29] S. Glisic, AI Algorithms in Networks
[30] S. Glisic, Explainable Neural Networks

RESEARCH

*The initial **S**trategy in **R**esearch segment (SoR) is elaborated within 6 research reports, defining the research foundation in six different research fields, prepared in the format of survey papers to be further edited with the departments and submitted for publication. Work on these materials is expected to provide a starting base for establishing the background in a specific field and generate ideas for project applications and publications of the corresponding research communities.*

#1 Quantum Computing and Neuroscience for Future Networks: Survey
Savo Glisic, Worcester Polytechnic Institute, Massachusetts
(to be offered to Departments of Neuroscience, ECE, CS, Mathematics)

https://www.ins-netgroup.com/wp-content/uploads/2024/02/1.pdf

Abstract- Recently significant effort has been invested in studying commonalities of human brain operation and advanced algorithms for machine learning to answer the question: Can the learning mechanisms, identified in the operation of the brain, be mimicked in artificial neural networks to enhance the learning efficiency with simultaneous reduction in complexity and power consumption.
At the same time, machine learning algorithms, on their own, become increasingly complex, resulting in complex neural networks. To speed up the machine learning algorithms, research on

7G networks will be looking for new computing technologies, like quantum (q-) computing (QC), and new models for complex networks that will enable us to efficiently control/optimize the processes run on them.
In this paper, under the umbrella of well-established complex networks theory, we provide a unified presentation of how quantum computing, implemented on near-future computers, can enable solving various problems in the above disciplines, otherwise difficult to solve by using classical (c-) approaches. The emphasis is on the commonalities in QC applications and modeling for the different systems listed above. For 7G network designers, the survey is expected to provide an insight into how much the research results in natural, QC based sciences can be integrated into new network paradigms to support above initiatives.

Index terms:7G networks, new paradigms in modern communication systems, QC, ML, complex networks, n-Sci, q- biology and q-chemistry for brain modeling, tensor networks, synchronization.

CONTENT

#2 Quantum vs Post-Quantum Security for Future Networks: Survey

Savo Glisic, Worcester Polytechnic Institute, Massachusetts
(to be offered to Departments, ECE, CS, Mathematics)

https://www.ins-netgroup.com/wp-content/uploads/2024/02/2.pdf

Abstract: Classical cryptography schemes have been compromised by the practical results on Quantum computers in recent years. Nowadays these schemes can be solved by using the Shor's algorithm. This paper provides a detailed survey of the work on so called Post-Quantum Cryptography (PQC) schemes, which are based on different principles, minimizing the threats coming from advantageous of quantum computers. Even so, post-quantum schemes do not completely solve the problem but rather represent a temporary solution. On the other hand, Quantum Cryptography (QC) and quantum key distribution (QKD), discussed also in this paper, offer the ultimate solution: by relying on entanglement between quantum states. At least in the beginning, a competition is anticipated between the two approaches to security schemes, so the paper provides comprehensive survey of both QC and PQC algorithms, enabling full understanding of pros and cons when it comes to the possible choices for implementation in future networks.

To further encourage the network designers to consider quantum solutions for future networks, the paper presents original, fundamental research work on LEO satellite network optimization algorithms for global QKD. The solutions using exclusively LEO orbits instead the combinations of LEO and GEO orbits, considered so far, enable up to two orders of magnitude power savings which is of importance when it comes to implementation of the network using power constrained terminals. The algorithms are designed for using Quantum Search Algorithms (QSA), like Grover algorithm, and Quantum Approximate Optimization Algorithms (QAOA), especially powerful for solving combinatorial optimization problems.

Index Terms: Post-Quantum Cryptography (PQC), Quantum Cryptography (QC), Quantum key distribution (QKD)

CONTENT

#3 Quantum Wireless Technology for Future Networks: Survey

Savo Glisic, Worcester Polytechnic Institute, Massachusetts
(to be offered to Departments, ECE, CS, Mathematics)
https://www.ins-netgroup.com/wp-content/uploads/2024/02/3.pdf

Abstract- Every new generation of mobile networks brings significant advances in two segments, enhancement of the network parameters within the legacy technologies and introduction of new technologies enabling new paradigms in designing the network. In the first class of enhancements the effort is to increase data rates, improve energy efficiency, enhance connectivity, reduce latency etc. In the second class of innovation in the past we have seen introduction of Software Defined Networks (SDN), Network function Virtualization (NfV) and Network Slicing (NS), massive use of Machine Learning (ML) and lately in the research for 6G, integration of satellite and terrestrial networks has attracted a lot of attention. For 7G, in this segment, we anticipate focus on optimum integration of ML and Quantum Computing (QC) with the continuous interest in the satellite networks for optimal Quantum Key Distribution QKD).

In this paper we present a comprehensive survey of the technology enablers for the above concept with special emphasis on the interdependency of the solutions chosen in different segments.

Index Terms- Quantum Computing (QC), 7G Networks, Quantum Key Distribution QKD), Continuous Variable QC

CONTENT

#4 Enabling Technologies for Quantum Security in Future Networks: Survey
Part1: Quantum Information Processing
Savo Glisic, Worcester Polytechnic Institute, Massachusetts
(to be offered to Departments, ECE, CS, Mathematics)

https://www.ins-netgroup.com/wp-content/uploads/2024/02/4.pdf

Abstract - Our recent paper provides a detailed survey of the work on Post-Quantum and Quantum Cryptography (PQC) schemes and emphasizes on their applicability in 7G networks. A comprehensive insight is provided into the schemes which could possibly replace RSA and ECC schemes.

The paper argues that most probably post-quantum schemes will dominate 6G networks and due to implementation complexity quantum solutions will be fully employed in 7G.

Since the paper focuses on the cryptography algorithms as a follow up, in a three-part paper, we discuss in detail the enabling technologies for the practical implementation of these algorithms.
In this, part 1, paper we cover the most important segments of quantum information processing for 7G .

Index Terms- Quantum Cryptography (QC), Quantum key distribution (QKD), Q memories, Quantum Networks, Satellite QN, QKD Over Suboptical Bands, Qubit Physics, Quantum Circuit Libraries, Implementation Examples of cv QKD hardware

Part 1: Quantum Information Processing in 7G

CONTENT

#5 Enabling Technologies for Quantum Security in Future Networks: Survey
Part 2: Quantum Networks
Savo Glisic, Worcester Polytechnic Institute, Massachusetts
(to be offered to Departments, ECE, CS, Mathematics)

https://www.ins-netgroup.com/wp-content/uploads/2024/02/5.pdf

Abstract - Our recent paper provides a detailed survey of the work on Post-Quantum and Quantum Cryptography (PQC) schemes and emphasizes their applicability in 7G networks. A comprehensive insight is provided into the schemes which could possibly replace RSA and ECC schemes.

The paper argues that most probably post-quantum schemes will dominate 6G networks and due to implementation complexity quantum solutions will be fully employed in 7G.

Since the paper focuses on the cryptography algorithms as a follow up, in a three-part paper, we discuss in detail the enabling technologies for the practical implementation of these algorithms.
In this, part 2, paper we cover the most important segments of quantum networks design.

Index Terms- *Quantum Cryptography (QC), Quantum Networks, Satellite QN, QKD Over Suboptical Bands,*

Part 2: Quantum Networks in 7G

CONTENT

#6 Enabling Technologies for Quantum Security in Future Networks: Survey
Part 3: Quantum Hardware in Future Networks
Savo Glisic, Worcester Polytechnic Institute, Massachusetts
(to be offered to Departments, Physics, ECE,)

https://www.ins-netgroup.com/wp-content/uploads/2024/02/6.pdf

Abstract - Our recent paper provides a detailed survey of the work on Post-Quantum and Quantum Cryptography schemes and emphasizes on their applicability in 7G networks. A comprehensive insight is provided into the schemes which could possibly replace RSA and ECC schemes.

The paper argues that most probably post-quantum schemes will dominate 6G networks and due to implementation complexity quantum solutions will be fully employed in 7G.

Since the paper focuses on the cryptography algorithms as a follow up, in a three-part paper, we discuss in detail the enabling technologies for the practical implementation of these algorithms.
In this, part 3 paper, we cover the most important segments of quantum hardware in 7G.

Index Terms- Q memories, Qubit Physics, Quantum Circuit Libraries, Implementation Examples of cv QKD hardware

Part 3: Quantum Hardware in 7G

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*Strategy on the **Program Implementation**: a) Activities on WPI level b) Work with the clusters of Departments c) Project Applications d) Activities on National/International Programs*

1. WPI open seminar on university transition from nano to QC based -technology
2. Work with clusters of WPI departments (as indicated in SoE and SoR segments) to establish the courses and create the research teams based on the seed research results provided by the Program.
3. Work on integrative project proposals on QC based technologies.
4. Editing the materials provided by the Program and turning them into the books.
   Four manuscript are prepared within the program and will be edited together with young faculties for final publications:
   Savo Glisic, WIRELESS QUANTUM NETWORKS: Intelligent Continuous Variable Technology, http://www.ins-netgroup.com/wp-content/uploads/2022/08/cover.pdf
   Savo Glisic, QUANTUM vs POST QUANTUM SECURITY: Algorithms and Design Technology, ,http://www.ins-netgroup.com/wp-content/uploads/2022/08/cover-2-.pdf
   S. Glisic, Quantum Computing in Complex Networks: Volume 2, https://www.ins-netgroup.com/uncategorized/quantum-computing-in-complex-networks-volume-2-2/
   S. Glisic, Quantum Computing in Complex Networks: Volume 1, https://www.ins-netgroup.com/uncategorized/quantum-computing-in-complex-networks-volume-1/

5. Program with the office of the President and office of the provost.
   a) Turning wifiUS program into Q-wifiUS program.
   b) Supporting President's office for initiatives for National QC program.

c) Elaborating the strategy for joining national alliances in QC
like Center for Quantum Networks/ NSF Engineering Research Center? https://cqn-erc.org

d) Elaborating the strategy for joining/initiating international alliances in QC like 7G alliance.

6. *Constant Work with the Departments on modifications/additions of the program*

DELIVERABLES

The activities on the implementation of the program can start at the beginning of 2024-2029

1. Establish thirteen graduate courses
2. Establish 6 research groups
2a. Produce and submit NSF project applications
3. Publish four voluminous books.
4. Publish 6 survey papers as a basis a seed paper for each research group.
5. Publish a series of research papers
6. Design undergraduate program for QC
7. Become a member of NSF Engineering Research Center. https://cqn-erc.org
8.Establish and become active within q-wifius.
9. Establish and become active within 7G alliance.