LIST OF SEMINARS

Dr. Mohsen Kavehrad
W.L. Weiss Chair Professor, Electrical Engineering
The Pennsylvania State University
University park, PA. 16802

1. **SEMINAR TITLE:** Multi-Input Multi-Output (MIMO); Potential Applications – Myth and Reality

ABSTRACT

In its relatively short history, research on MIMO communications has reached to a high level of accomplishment with a very rich literature.

The great success "STORY" of MIMO in RF communications has certainly motivated the desire of IEEE standards bodies to explore its capabilities in various forms of communications.

As communications researchers rush to this potentially promising field, they tend to ignore the many unique properties and constraints of MIMO and start making wishful assumptions. Unfortunately, currently available results for RF communications cannot be applied to practical MIMO links that exhibit their own unique characteristics with underlying different statistical channel models and practical transmission techniques.

This seminar is an effort to provide further insights into the performance of single-user MIMO links that ultimately are able to provide the largest achievable capacity, presenting the maximum diversity order achievable through the employment of multiple transmitter/receivers. We further discuss the effect of spatial correlation and demonstrate the necessity of enough transmitter separation and strict requirements to achieve the promised theoretical diversity advantages.
Furthermore, we offer examples where the MIMO payoff is not worth the additional hardware costs, today.

2. **SEMINAR TITLE:** Multi-band, Multi-service, Sensing Metamaterials; Myth & Reality

ABSTRACT

Demands by the communications industry for greater bandwidth push the capability of conventional wireless technology. Part of the Radio Spectrum that is suitable for mobility is very limited. Higher frequency waves above 30 GHz tend to travel only a few miles or less and generally do not penetrate solid materials very well.
Unmanned Aerial System applications require electronic scanning antenna capabilities, in challenging environmental conditions, over very large bandwidths. In addition to that, it is desirable to have as much reduction as possible in size, weight, power and cost.

Metamaterials are recently being played with by periodic repetition of some inclusions in a host medium, which may be described as effective media characterized by a set of equivalent constitutive parameters. Self-similarity in creating periodic structures is the basis of building volume or 2D holographic components. The latter does more than periodic repeats.
Similar, but more advanced concepts (fractal in nature) are used to model phase screens used in modeling the atmospheric turbulence.
Unfortunately, metamaterials (MTMs) are anisotropic (direction-dependent) and this makes their application limited in terms of use as antennas for mobile platforms. However, conceptually can be applied to make phased-arrays, beam-forming, and beam scanning.
As for lensing and fixed platform imaging, the story is very different, as super-lens is expected to be a byproduct.
Nevertheless, even if metamaterials become readily available, the atmosphere around the globe cannot be replaced. Neither, broadband wireless connectivity to a mobile can be achieved via fiber optics.
This seminar, presents a Hybrid RF and Wireless Optical solution to provide adaptive sensing in an opportunistic fashion, with or without metamaterials. A byproduct of the latter will be broadband and reliable global connectivity.

3. **SEMINAR TITLE:** Optical Wireless Applications - A Solution to Ease the Wireless Airwaves Spectrum Crunch

ABSTARCT

Demands by the communications industry for greater and greater bandwidth push the capability of conventional wireless technology. Part of the Radio Spectrum that is suitable for mobility is very limited. Higher frequency waves above 30 GHz tend to travel only a few miles or less and generally do not penetrate solid materials very well. This offers a sustainable solution for the current Spectrum Crunch in the lower microwave bands. One mission of this seminar is to demonstrate practical and usable networks that can select a ***self-limiting*** link distance, allowing spectrum reuse. The motivation for operators of such bands to actually choose to self-limit is that by doing so, they improve the signal-to-noise against competing users at a lower cost than trying to overcome interference. These characteristics of wave propagation are not necessarily disadvantageous as they enable more densely packed communications links. Thus, high frequencies can provide very efficient spectrum utilization through "***selective spectrum reuse***", and naturally increase the security of transmissions. Optical systems and networks offer a far greater bandwidth. This means new devices and systems have to be developed. Semiconductor Light Emitting Diode (LED) is considered to be the future primary lighting source for buildings, automobiles and aircrafts. LED provides higher energy efficiency compared to incandescent and fluorescent light sources and it will play a major role in the global reduction of carbon dioxide emissions, as a consequence of the significant energy savings. Lasers are also under investigation for similar applications. These core devices have the potential to revolutionize how we use light, including not only for illumination, but as well; for communications, sensing, navigation, positioning, surveillance**,** and imaging.

4. **SEMINAR TITLE:** Optical Wireless: Theory and Applications

ABSTARCT

Demands by the communications industry for greater and greater bandwidth push the capability of conventional wireless technology. Optical systems and networks offer a far greater bandwidth. This means new devices and systems have to be developed.
Semiconductor Light Emitting Diode (LED) is considered to be the future primary lighting source for buildings, automobiles spacecraft and aircrafts.
LED provides higher energy efficiency compared to incandescent and fluorescent light sources and it will play a major role in the global reduction of carbon dioxide emissions, as a consequence of the significant energy savings.
Lasers are also under investigation for similar applications. These core devices have the potential to revolutionize how we use light, including not only for illumination, but as well; for communications, sensing, navigation, positioning, surveillance**,** and imaging.
This presentation covers the evolutionary path of the field.

5. **SEMINAR TITLE:** Reconfigurable Optical Wireless Applications in Data Centers

ABSTRACT

Data centers (DCs) are a critical piece of today's networked applications in both private and public sectors. The key factors that have driven this trend are economies of scale, reduced management costs, better utilization of hardware via statistical multiplexing, and the ability to elastically scale applications in response to changing workload patterns. A robust *datacenter network fabric* is fundamental to the success of DCs and to ensure that the network does not become a bottleneck for high-performance applications. In this context, DC network design must satisfy several goals: high performance (e.g., high throughput and low latency), low equipment and management cost, robustness to dynamic traffic patterns, incremental expandability to add new servers or racks,
and other practical concerns such as cabling complexity, and power and cooling costs. Current DC network architectures do not seem to provide a satisfactory solution, with respect to the above requirements. In particular, traditional *static* (wired) networks are either:

(i) *overprovisioned* to account for worst-case traffic patterns, and thus incur high cost (e.g., fat-trees or Clos), or

(ii) *oversubscribed* (e.g., simple trees or leaf-spine architectures) which incur low cost but offer poor performance due to congested links. Recent works have tried to overcome the above limitations by augmenting a static (wired) "core" with some flexible links (RF-wireless or optical). These *augmented* architectures show promise, but offer only incremental improvement in performance. Specifically, RF-wireless based augmented solutions also offer only limited performance improvement, due to inherent interference and range constraints of RF links. Optical solutions offer high-bandwidth links and low latency, but have limited scalability, offer only limited flexibility (e.g., bipartite-matchings

between the racks), and have a single point of failure. Furthermore, all the above architectures incur high cabling cost and complexity.

A robust datacenter network is fundamental to the success of critical and high performance networked applications today. Designing a datacenter network is challenging as it must simultaneously satisfy several goals: high-throughput and low latency, low equipment and management cost, robustness to dynamic traffic patterns, incremental expandability, and other practical concerns such as cabling complexity, energy footprint, and cooling costs.
This project explores an alternative design point—a *fully flexible* and *all-wireless* datacenter inter-rack network based on free-space optical (FSO) links. This vision, if realized, will offer unprecedented qualitative and quantitative benefits over state-of-the-art solutions:

(1) A flexible network can provide performance comparable to overprovisioned solutions with less infrastructure cost by adapting the topology to the prevailing traffic patterns;
(2) It eliminates cabling complexity, and cooling and power overheads;
(3) It acts as an enabler for datacenter operators to consider experimental topology designs that would otherwise be unrealizable; and
(4) It can take us closer to the vision of an energy-proportional datacenter by allowing operators to selectively enable links.

There are several fundamental challenges that need to be addressed to make this vision practical:

(i) design of practical high-throughput FSO links for datacenters that are reconfigurable with low latencies;
(ii) algorithmic foundations for designing flexible topologies; and
(iii) scalable network management mechanisms to guarantee correctness and performance.

We will discuss these issues in an oral presentation.

6. **SEMINAR TITLE:** Academic / Industrial Engineering Experience

ABSTRACT

After discussing required parameters to consider in engineering research, approaches to engineering education will be discussed. Elements of making engineering education fun will be described and some success stories as well as vision for future will complete the seminar.