

## FSO-based relaying/backhauling architecture

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Purpose:

Propose a low cost and high throughput relaying/backhauling architecture based on free space optics (FSO)

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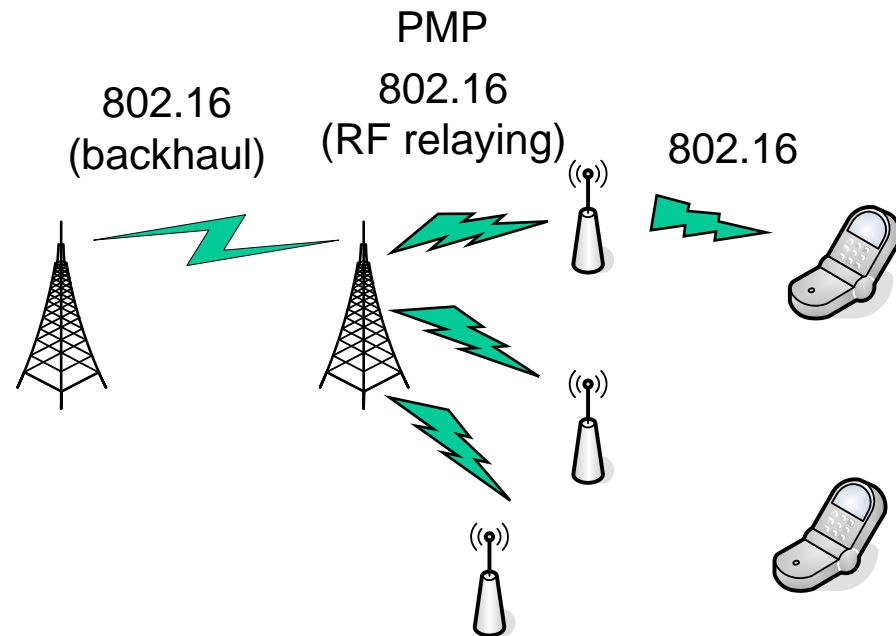
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# Outline

- RF relaying
- RoF (Radio over Fiber) relaying
- Proposed FSO(Free Space Optics) relaying and backhauling
- Summary

# RF relaying

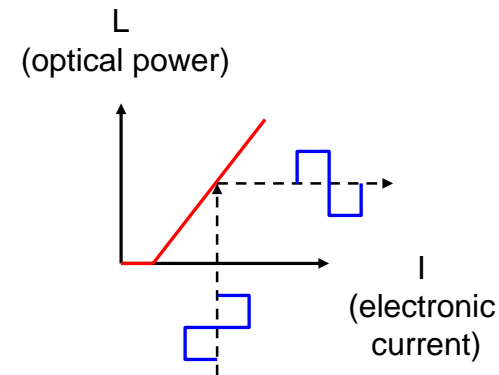
- Relaying solutions
  - AF: Amplify-and-Forward
  - DF: Decode-and-Forward
- Benefits:
  - Reach extension
  - Increase capacity
  - Improved uniform data rate coverage
- Problem
  - Intra cell inference by relay station?
  - Costly RF relaying equipment



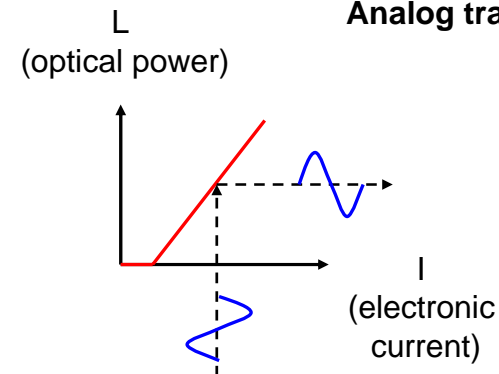
# Basics of optical communication

- Principle of optical communication:
  - Transmitter:
    - Direct modulation: LED, LD (FP, DFB laser)
    - External modulator: MZM, EAM
  - Receiver:
    - IMDD: PIN, APD diode
- Applications
  - Digital transmission
    - Optical backbone
  - Analog transmission
    - CATV, RoF

**Digital transmission**



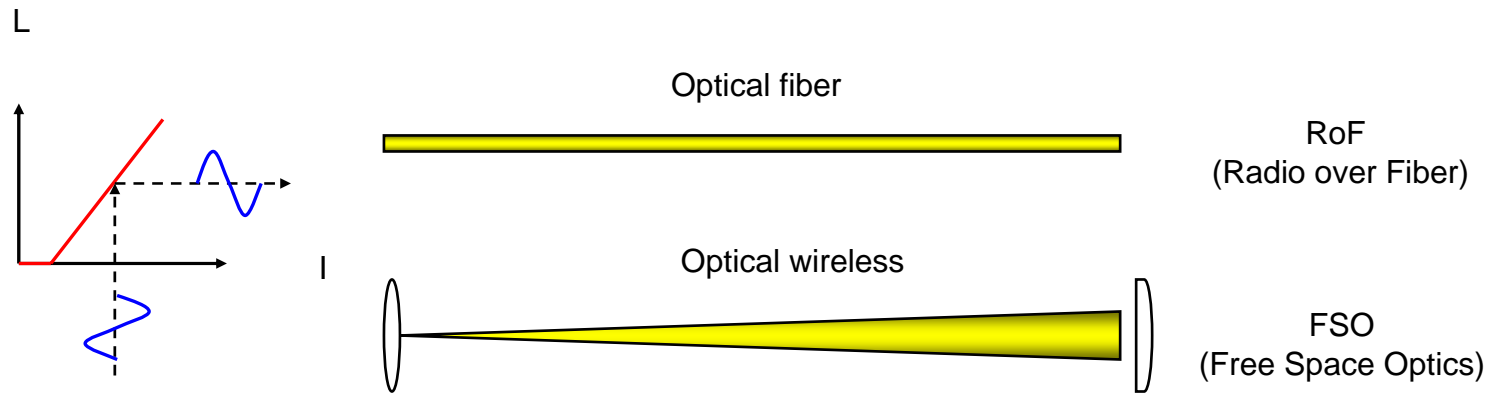
**Analog transmission**



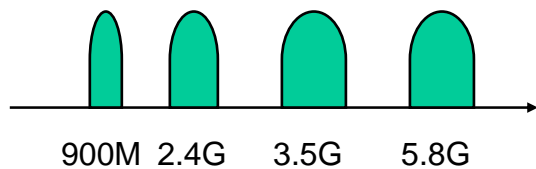
# Optical relaying

- Subcarrier Modulation (SCM) for RF signal relaying by analog transmission

2G, 2.5G, 3G, WLAN, WiMAX, 4G/over optics

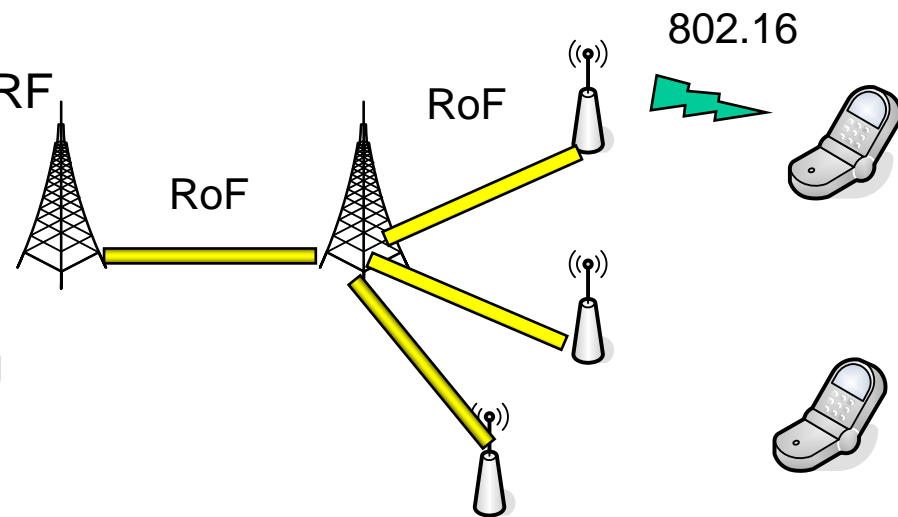


2G, 2.5G, 3G, WLAN, WiMAX, 4G



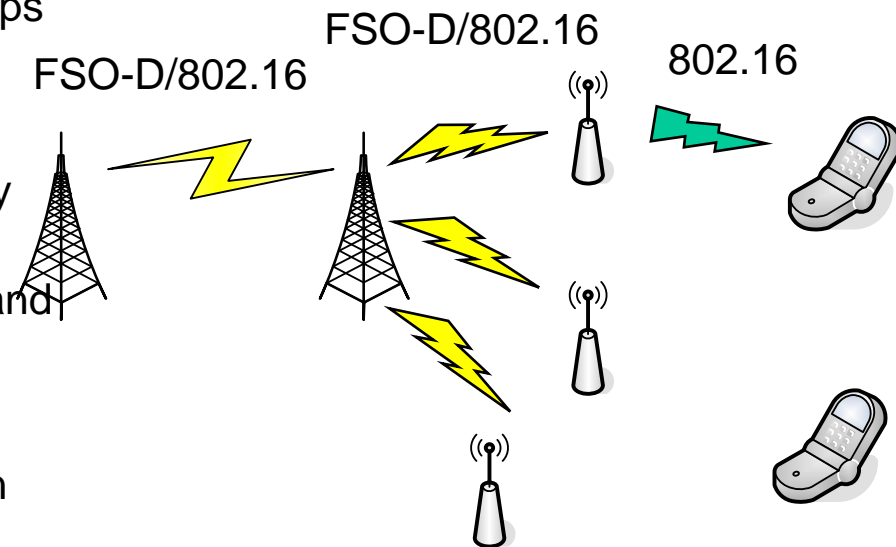
# RoF relaying

- Pros:
  - Higher capacity than RF relaying
  - Lower equipment cost than RF relaying
  - Better resource reuse
- Cons:
  - High installation engineering cost



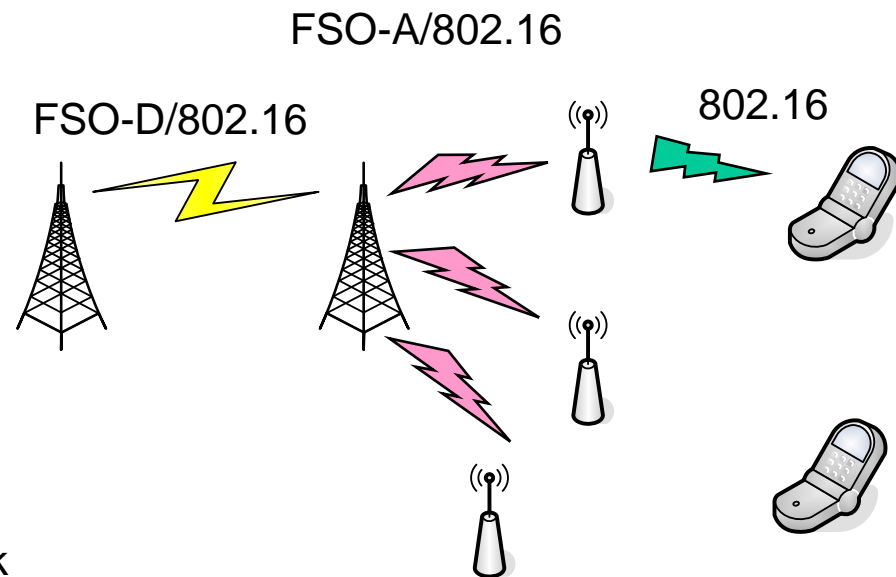
# Proposed digital FSO relaying

- Features of Digital FSO (FSO-D):
  - Long distance, high bandwidth, less power (e.g. throughput: 1Gps for 4km)
  - Like a directional antenna with large antenna gain (dBi)
  - Low interference/noise immunity
- Pros:
  - Combine the advantage of RF and RoF relaying
  - High throughput yet low installation cost
  - 10 times backhaul capacity than RF backhaul
- Cons:
  - Sensitive to weather condition (Fog), but this could be solved by hybrid RF/FSO system @ 99.999% reliability



# Proposed analog FSO relaying

- Requirement of of Analog FSO (FSO-A):
  - Multi-standards radio frequency over FSO
  - Signal transparency: without format conversion compared to digital FSO
- Pros:
  - Combine the advantage of RF and RoF relaying
  - High throughput yet low installation cost
  - Suitable for PMP network
  - Easy to migration to 4G network
- Cons/Difficulties:
  - Linearity of laser diode
  - Up/down convert maybe needed
  - Products not available yet





# Summary

- A hybrid RF/digital FSO architecture is proposed for improving the capacity/throughput of relaying network and backhaul system
- A hybrid RF/analog FSO architecture is proposed for improving the capacity/throughput of relaying network
- A novel analog FSO concept is proposed for migrating to future systems
- A novel analog FSO concept is proposed to support multi-standard wireless over FSO to accelerate the deployment of next generation broadband wireless access system

# References

- X. H. Yu, G. Chen, M. Chen and X. Gao, "The FuTURE Project in China," IEEE Commun. Mag., pp. 70 - 75, 2005.
- H. A. Willebrand and B. S. Ghuman, "Fiber optics without fiber," IEEE Spectrum, pp. 40-45, 2001.
- H. Wu, B. Hamzeh and M. Kavehrad, "Achieving carrier class availability of FSO link via a complementary RF link," IEEE 38th Asilomar Conf. Signals, Systems and Computers, pp. 1483 - 1487, 2004.