



Research Consortium in Speckled Computing

# Spatial Reuse in CDMA Enabled SpeckNets

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# Context

- Next generation Speck communications
- Random access protocols are typically used in wireless sensor networks...
  - e.g. Carrier Sense Multiple Access (CSMA)
  - ... can we improve on this?
- Solutions which are suitable for very distributed networks
  - No central control or synchronisation
- Low power
- Research theme: Code Division Multiple Access (CDMA)



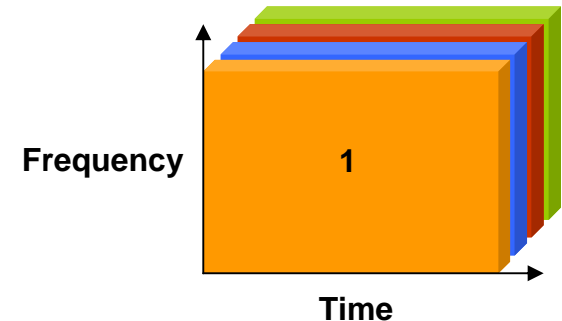
# Summary

- Introduction
- The Near Far Problem
  - Cellular Networks
  - CSMA Networks
  - Ad hoc CDMA Networks
- Exclusion Zones Around Specks
  - Optimisation
- Spatial Reuse Comparison
- Deployment Considerations
- Conclusions



# Introduction

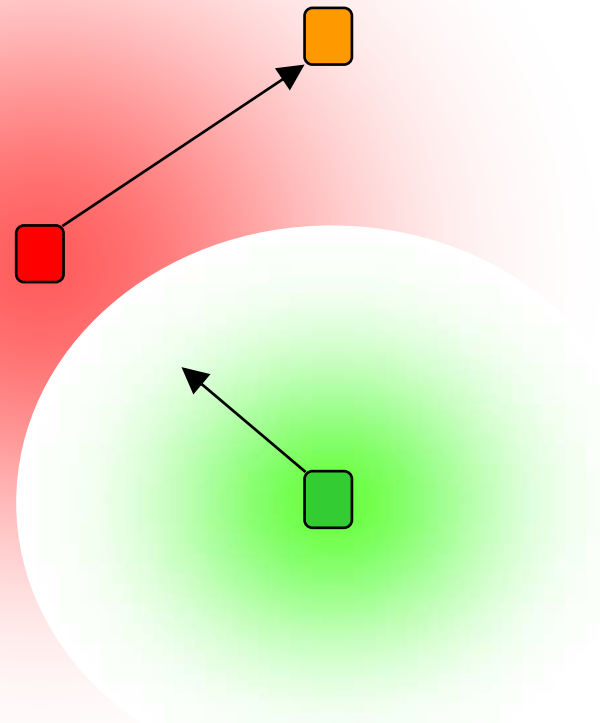
- Code division multiple access (CDMA) is a scheme for sharing the radio channel according to codes
  - Each user has a distinct code
  - Some difficulties...
    - Code allocation / management
    - The Near Far Problem
- This work is concerned with managing the Near Far Problem in a simple way
  - SpeckNets may possess a lot of redundancy
    - Perhaps we can manage Near Far through controlling the positions of active Specks
  - CDMA could provide much better spatial reuse of the channel than random access protocols (CSMA)



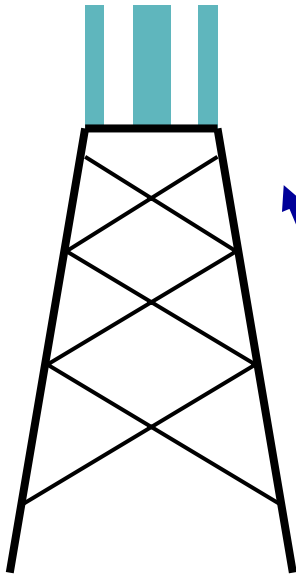
# The “Near Far” Effect

- Desired signal is “swamped” by nearby transmission
  - Signals arrive at the same time in the same frequency band
    - Orders of magnitude difference in range
    - Orders of magnitude difference in amplitude

*The blue node can hardly “hear” the green transmission, because the red transmission arrives with much higher power.*



# Near Far Management in Cellular Networks



Base Station

**Closed Loop  
Power Control**

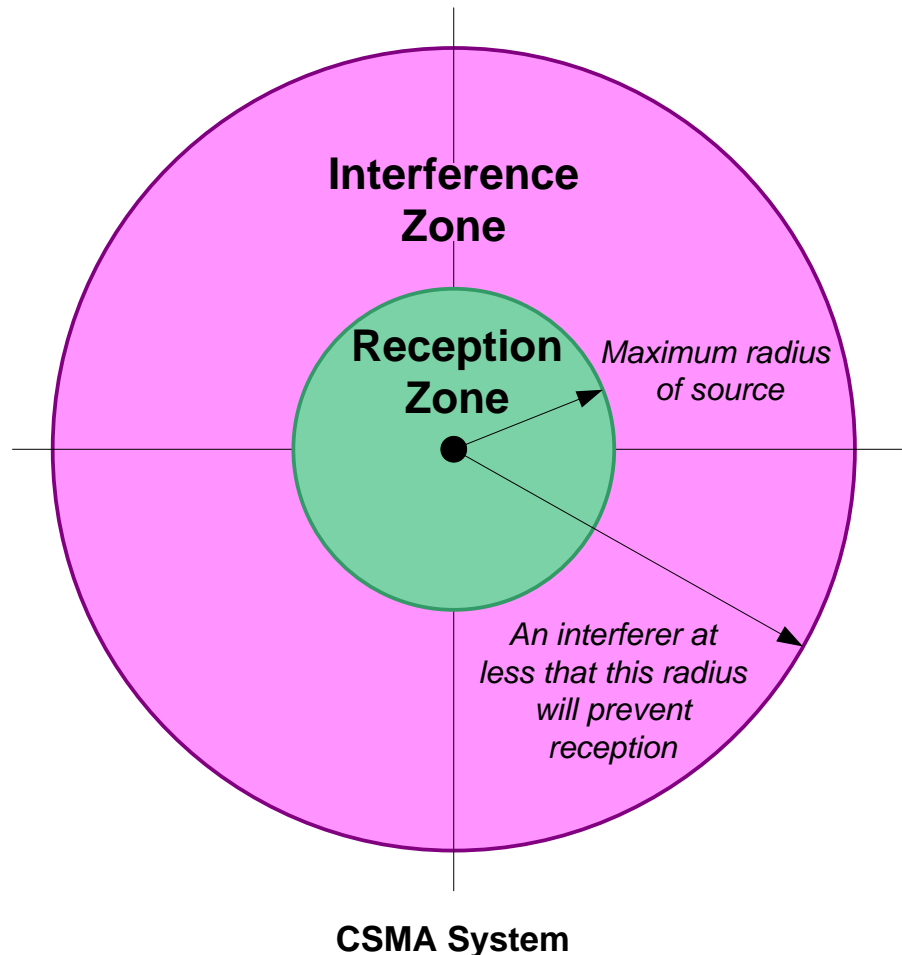


Mobile Terminal

**Power control updates 1500 per second!**

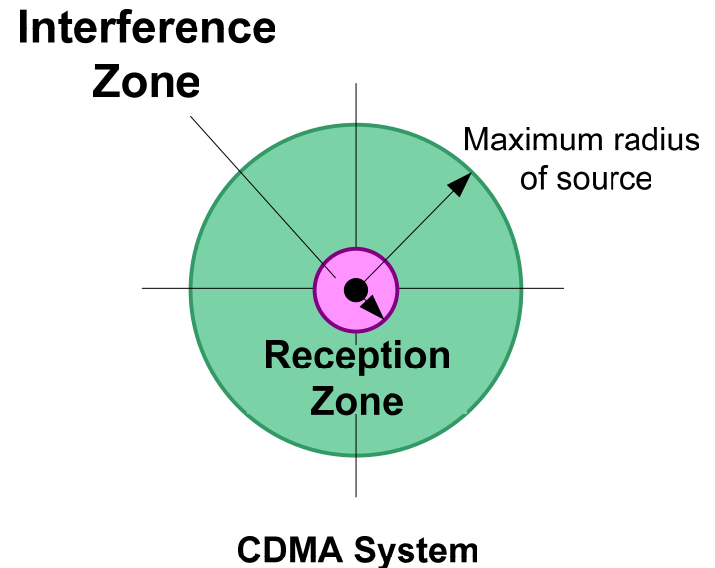
# CSMA Networks

- Can define two zones...
  - Reception Zone (inner)
  - Interference Zone (outer)
- Interferers outwith the reception zone can cause catastrophic interference
- For a transmission to be successful, require no other activity within the Interference Zone
- Transmission takes up quite a lot of space!



# Ad Hoc CDMA Networks

- The same two zones...
  - Reception Zone
  - Interference Zone
- Now the Interference Zone is **INSIDE** the Reception Zone
- As before, no transmissions allowed in the Interference Zone
- Much less space consumed by the transmission!
- Better ***spatial reuse*** of the radio channel.



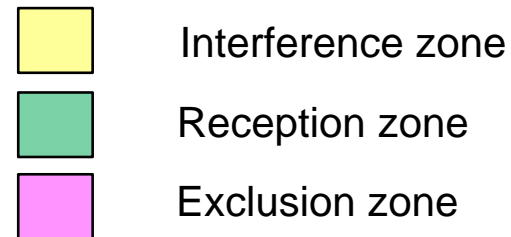
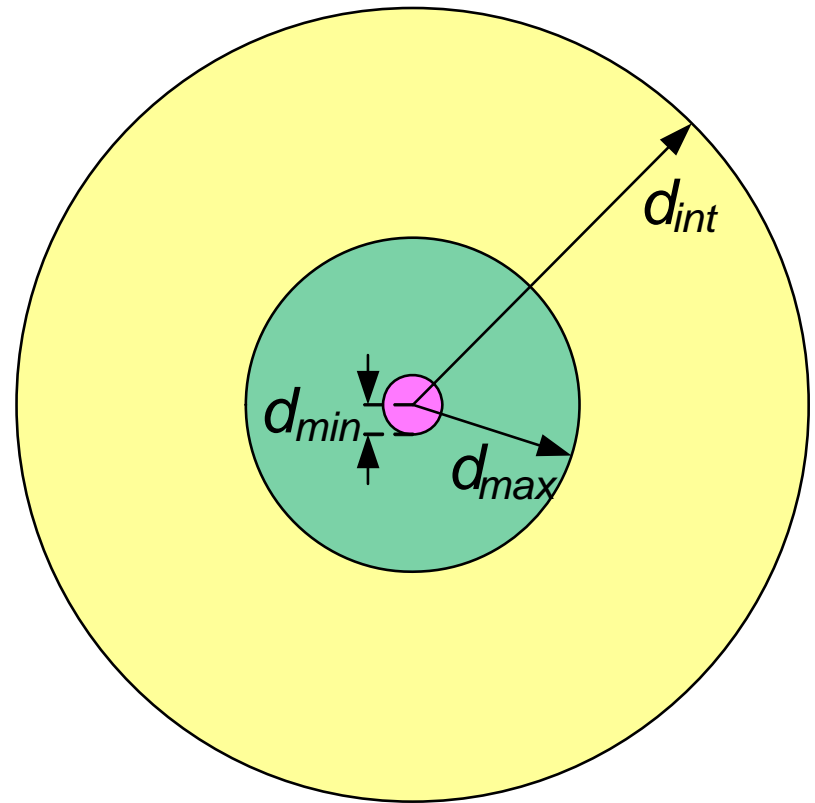
# Interference in CDMA

- CDMA codes are (almost!) orthogonal so sources present very little interference to each other
- In CSMA, the whole signal power contributes interference
- The processing gain of the CDMA system ( $G_p$ ) is an important parameter
  - Interference in CDMA systems is typically lower by the factor  $G_p$  compared to CSMA systems



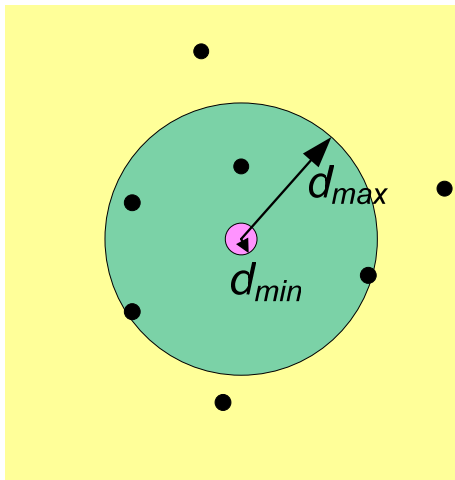
# Exclusion Zones Around Specks

- Provide an Exclusion Zone in the area around each receiving node
- Small area compared to range of communication
- How big should the Exclusion Zone be?
  - To maximise range
  - To minimise transmission power
- Define minimum separation of (active) Specks

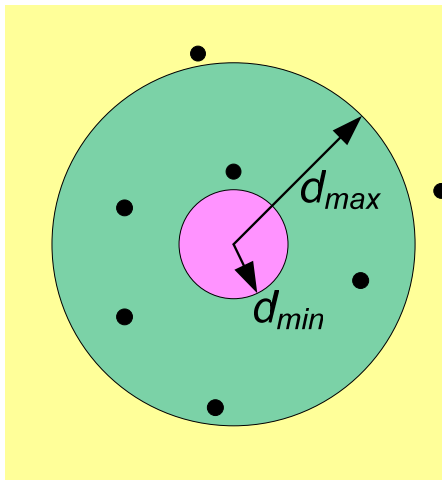


# Optimising the Exclusion Zone

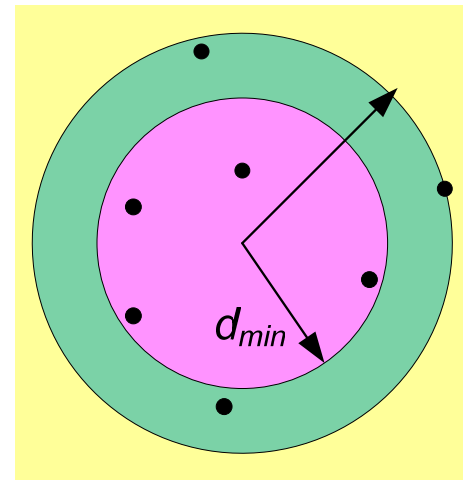
- Relationship exists between interference parameters and radii
  - There is an optimum radius to maximise coverage area
  - Not helpful just to maximise range... get a thin ring!
  - Alternatively can optimise for lowest transmit power



***Smallest  
Exclusion Zone***



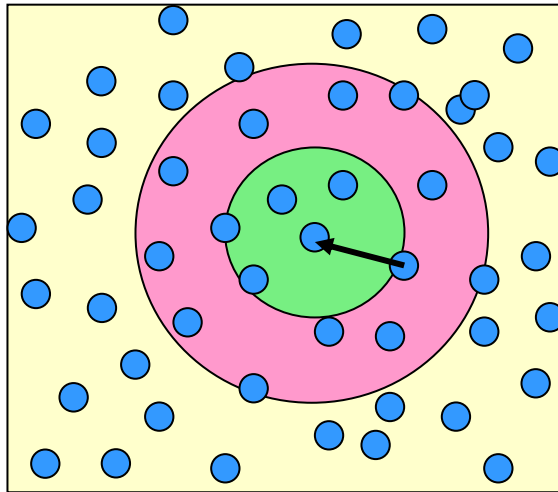
***Biggest  
Coverage Area***



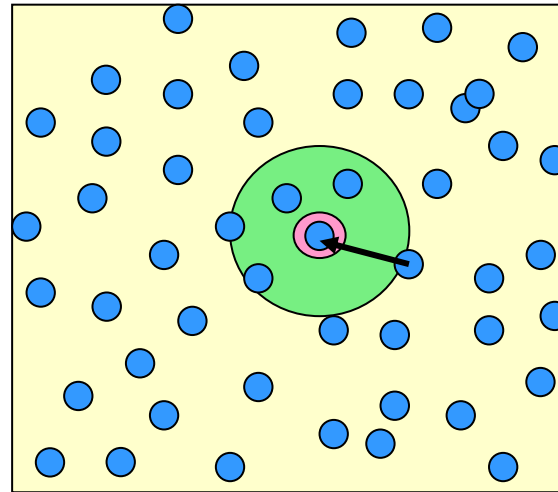
***Longest Range***

# Spatial Reuse Comparison

- Force the Reception Zones to equal area / volume
- Compare Interference Zones
  - Expect much bigger Interference Zone in CSMA system
  - Want to quantify the difference
- Spatial reuse of the radio channel
  - Compare the area / volume “consumed” by a transmission
  - Defines how closely concurrent transmissions can be spaced



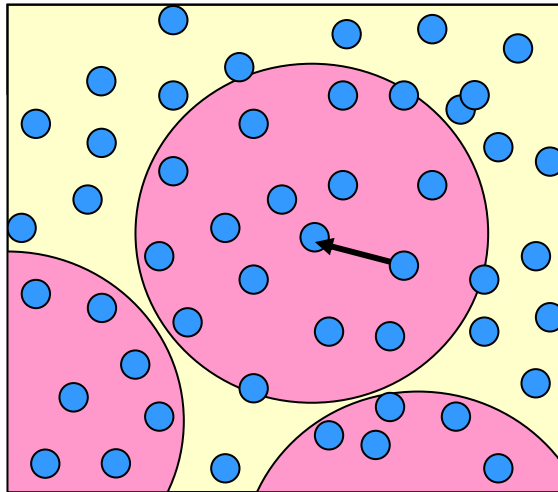
**CSMA**



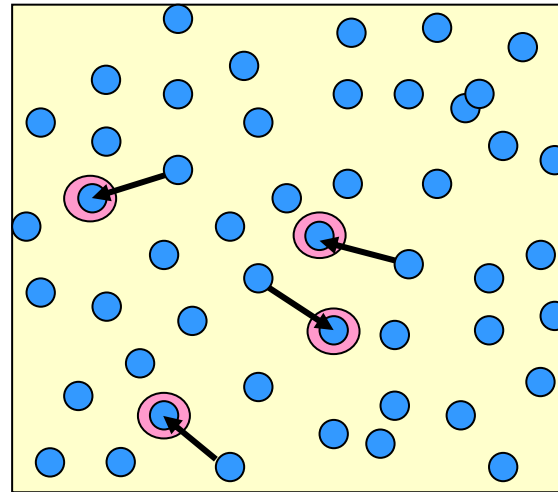
**CDMA**

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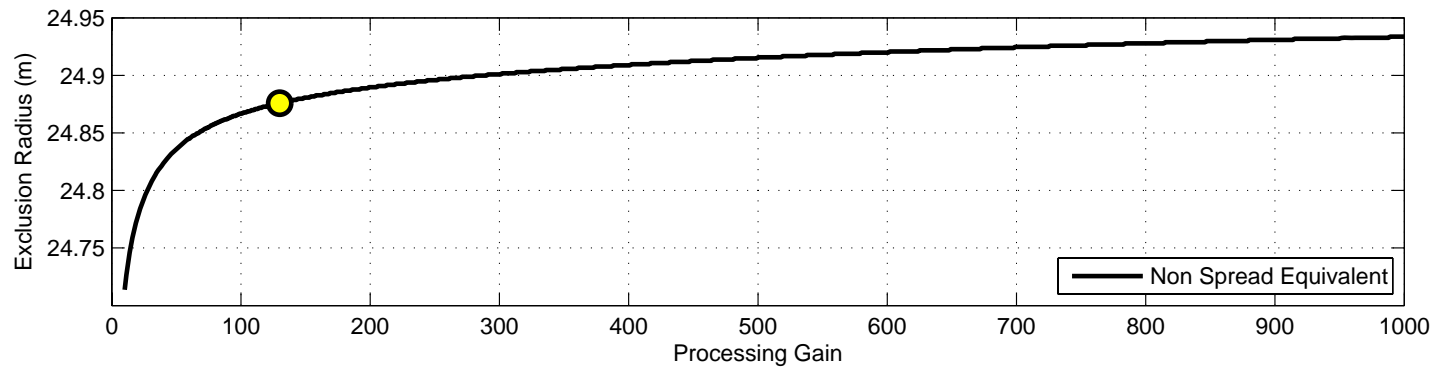
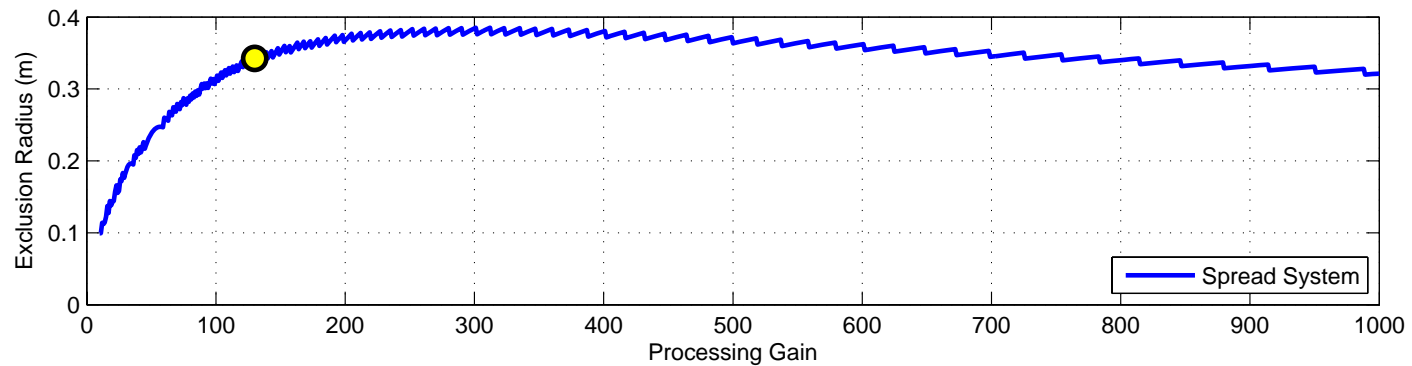
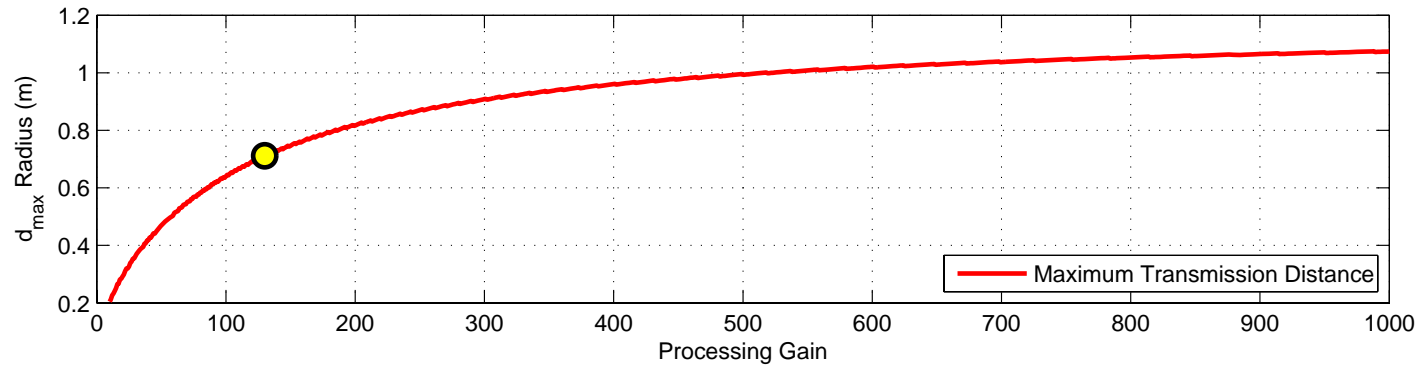


**CSMA**

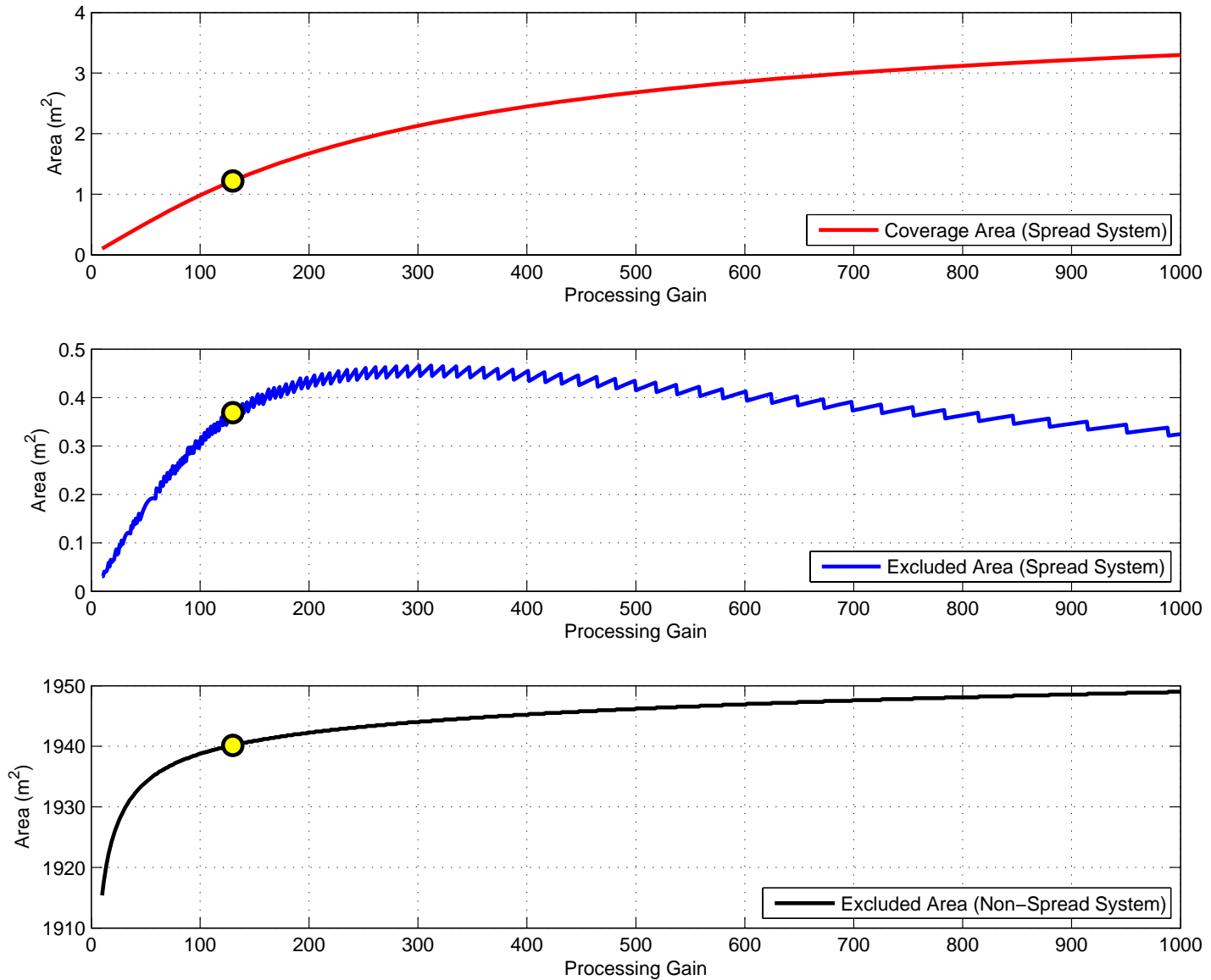


**CDMA**

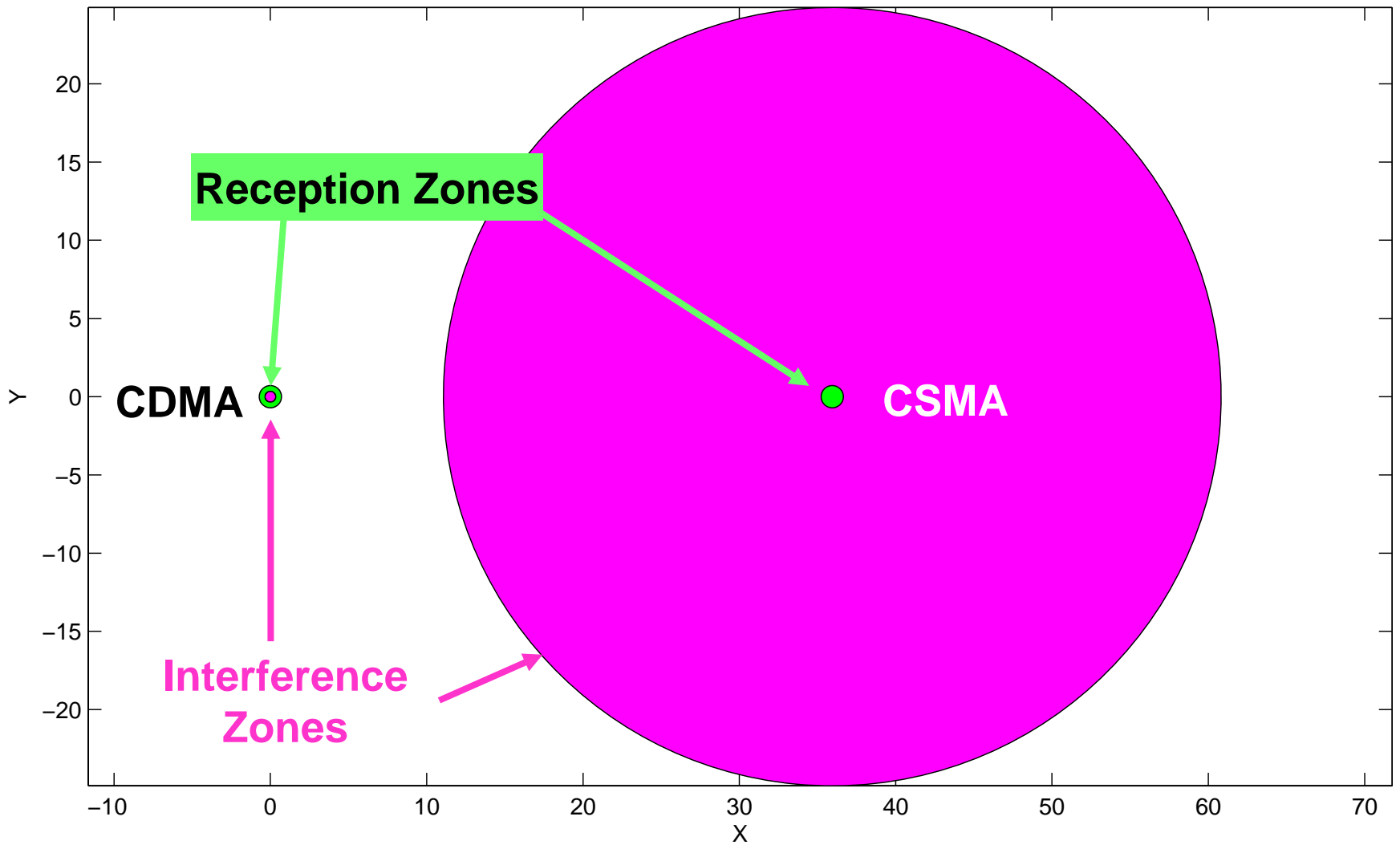
# Indicative Results - Radius



# Indicative Results - Area



# Comparison of Results



# Implementing Exclusion Zones

- SpeckNets are by nature redundant networks...
  - So it is likely that most nodes will be asleep at any given time
- Can we control their waking times in a spatially aware manner?
  - Provide exclusion zones by ensuring minimum separation of “active” nodes
  - Some algorithm required for thinning out the Specks
  - Network should evolve spatially as some nodes “sleep” and others “wake up”.



# Conclusions and Further Work

- The Near Far Problem can be controlled through managing the spatial distribution of active Specks
  - “Thinning out” Specks once deployed could be a simple solution
- CDMA allows better spatial reuse of the channel
  - This varies according to several parameters... (the results presented here are just an example)
  - Further work includes analysing the effect of these parameters on spatial reuse



# Summary

- The Near Far Effect is a problem in CDMA networks
  - Cellular networks have central control and more resources...
  - ... ad hoc SpeckNets require a much simpler means of controlling the effect
- This work analyses the spatial relationships of communicating Specks
  - CSMA versus CDMA comparison
    - Less interference in CDMA networks
    - Transmissions take up much less “space”
    - Increased spatial reuse of the channel
- Some means of controlling spatial separation required
  - SpeckNets offer a high degree of redundancy
  - Potential to duty cycle in a spatially aware manner

