Efficient Design of Wireless Networks for Faster Compression Rates

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In the modern age, wireless communication networks are incredibly energy consuming. For example, BT alone accounts for **1% of the UK's total energy** consumption [1].
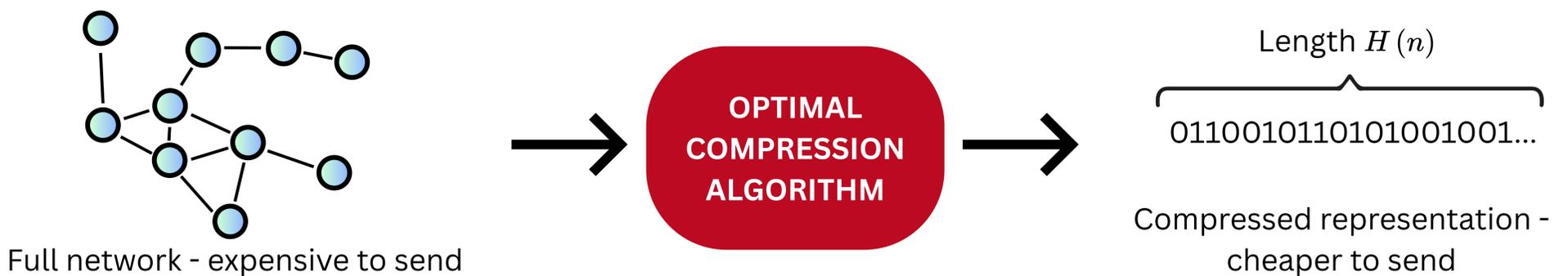
Individual points in a network are called 'nodes'. Two nodes can only communicate if they both know the structure of the network, allowing them to compute the best 'route' through the network. **Network compression** is used to represent the network more efficiently, so that less routing data needs to be transferred, meaning **less energy expenditure,** and **greener telecommunications.**

RESEARCH QUESTION: How big is the smallest compressed representation of the network?

A **compression algorithm** compresses a network into a smaller binary representation. The **smallest possible representation** has length $H(n)$ which we call the **entropy of the network**. However, the **entropy is incomputable**, even by our fastest supercomputers. An estimate based on infinitely large networks H_∞ is available [2], so in our research, we prove for an n user network:

$$H(n) < \frac{1}{2}n(n-1)H_\infty + \underbrace{dn\log n}_{\text{Term (1)}} + \underbrace{An^\alpha \log n}_{\text{Term (2)}} + \underbrace{Bn^\beta}_{\text{Term (3)}}$$

In other words, **we provide an estimate of the entropy that improves in accuracy as size increases.** Here, α is related to the smoothness of connections, β is related to the complexity of the network domain, and d, A and B are constants. Each of the labelled terms point to a **practical way to improve network communication efficiency**, which we discuss below.

Full network - expensive to send → **OPTIMAL COMPRESSION ALGORITHM** → Length $H(n)$

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Compressed representation - cheaper to send

Term (1): $dn\log n$
**Distribute Nodes in a Regular Structure (reduce uncertainty)**
- Our bound assumes maximum randomness
- Implement **regular structure** where possible to reduce randomness
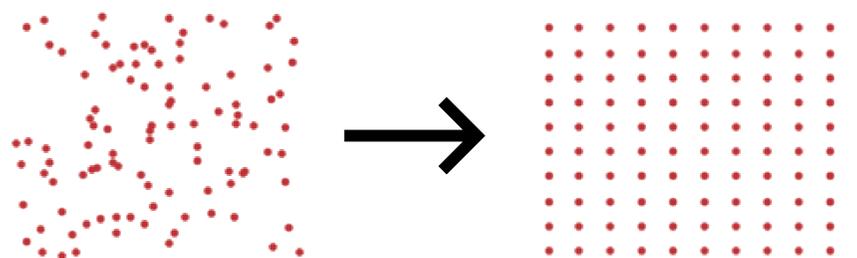
Term (2): $An^\alpha \log n$
**Invest in More Reliable Connections (reduce α)**
- Reduce changes in connection probability over small distances
- Reduce background noise in the environment
- Choose a signal that decays faster over distance
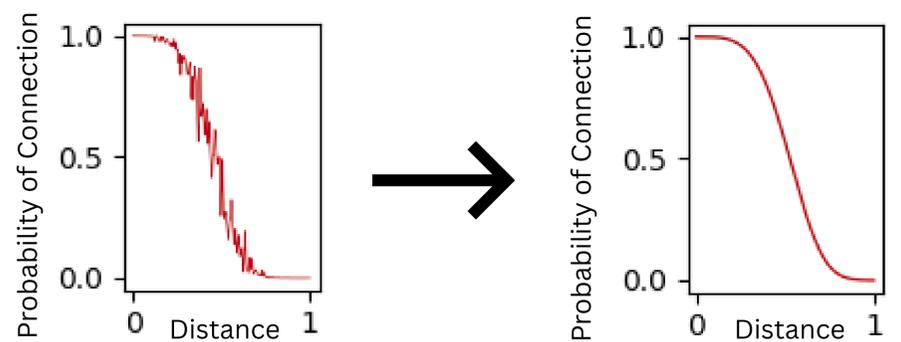
Term (3): Bn^β
Restrict the Network to a Smoothly Bounded Area (reduce β)
- Complicated domain means unpredictable distance distribution
- Simple, regular boundaries make compression easier
- Pratically, implement connections across sharp corners
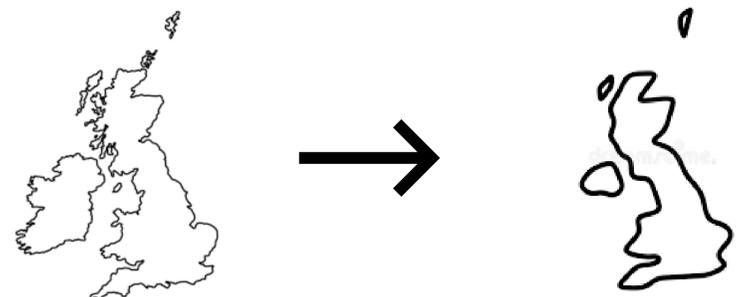
Conclusion & Future Work: We have proved a quantitative bound on the optimal compression size of wireless network models. This allows efficient power allocation to ensure more efficient and greener wireless communications. In future work, we aim to extend these results to networks of moving devices, and to distributed compression settings.

[1] Watson, H. (2022) How BT Group is making our networks more energy efficient, Available at: https://newsroom.bt.com/how-bt-group-is-making-our-networks-more-energy-efficient (Accessed: 09 February 2026).
[2] Janson, S. (2014) Graphons, cut norm and distance, couplings and rearrangements., New York Journal of Mathematics 4 .