

Switching, Networks and Maglev

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ABSTRACT: The first electric telecommunication systems utilized hardwired point-to-point connections, then gradually progressed to switchboards, automated mechanical circuit switching (relays) and eventually electronic switches. But the Internet revolution didn't happen until circuit switching gave way to *packet switching*, which optimizes channel capacity while minimizing transmission latency and increasing communication robustness. We are now on the verge of a similar revolution in high speed ground transportation. Electronically stabilized maglev vehicles and passive maglev track switches have been demonstrated and are ready to implement *maglev packet switching*, with the potential to vastly increase the utility and cost-effectiveness of ground transportation.

1 SWITCH TECHNOLOGY

Over the last several decades many commercial, government and academic organizations have investigated maglev transportation technology, greatly increasing our knowledge and understanding of both the underlying physics and the techniques for effective implementation. Maglev systems constructed in Germany, Japan and China have clearly demonstrated the technical feasibility of high speed operation. And yet, in spite of those impressive achievements, commercial acceptance of maglev transportation has been elusive. Government studies have made the reason abundantly clear — maglev systems, in their present embodiments, are simply not cost effective (FRA 2005).

One of the most limiting features of present embodiments is track switching. Conventional maglev designs rely on ponderous mechanical track switches that are massive, expensive and slow, resulting in mandatory headways of up to several minutes between successive trains and placing a severe limit on system throughput. An analogous situation existed in the telecommunications industry from the completion of the first telegraph line in 1844 until very recently. Long distance communication systems first utilized hardwired point-to-point connections, then progressed to switchboards, *circuit switching* using mechanical switches (relays) and eventually electronic switches. But the Internet revolution did not happen, and could not happen,

until circuit switching gave way to a fundamentally different technology called *packet switching*.

Packet switching was invented in the 1960's, first by Paul Baran at Rand Corporation in the US and later by Donald Davies at the National Physical Laboratory in the UK. In this paradigm discrete blocks of data, or packets, travel between network nodes over data links shared with other traffic. At each network node, a routing algorithm selects the best route to move packets toward their destinations, based on various metrics and the capacity available on the route choices. After a route is determined for one packet, it is entirely possible that changing conditions will cause the routing algorithm to select a different route for the next packet, with the result that packets from the same source headed to the same destination can be routed differently. Packet switching optimizes the use of the channel capacity available in a network, minimizes transmission latency (the time it takes for data to pass across the network), and increases the robustness of communication.

The packet switching concept was so different from established practice that it was largely ignored, at first. But its flexibility and promise resulted in its adoption for use in the ARPANET, in the 1970's, which of course led to the development of the Internet as we know it today. From its commercial inception in 1989, the Internet became a worldwide phenomenon in little more than a decade. The use of packet switching in that application has been so

successful that it is now supplanting nearly all other forms of data transmission, even for telephone traffic.

So how does this relate to maglev? *Conventional maglev is still stuck in the circuit switching paradigm, crippling its potential. The time has come for maglev packet switching.*

2 TRAINS VS. PACKETS

All major maglev implementations constructed thus far have been “maglev trains”, basically a nineteenth-century transportation mode with twentieth-century technology grafted on to replace the wheels, and dependent on mechanical track switch technology (circuit switching). Despite being “trains”, these maglev systems are not incremental improvements of existing infrastructure. They require completely new guideways constructed on new rights-of-way at tremendous cost. That has been their downfall. They are simply far too expensive to be cost effective, so no commercial entity will purchase them. Their construction and operation is contingent upon government subsidies, and thus far the most any government has been willing to bankroll is the 30 km Shanghai MagLev Demonstration Operation Line.

If the railroad metaphor could be dropped, however, and a maglev transportation system designed from scratch to incorporate packet switching, the result would be revolutionary improvements in operating characteristics and system economics. To be feasible, such a system would require particular features, such as:

- Instant Track Switching — slow mechanical switches must be replaced by instant track switches that allow flexible vehicle routing and scheduling. Vehicles must be able to pass through track switches without delay or impediment.
- Automated Vehicle Control — carrying an operator in each vehicle would decrease performance and safety while greatly increasing operating cost.
- Track Separation — Automated tracks must be physically separated from other transportation modes, particularly traffic on streets or highways, to prevent accidents or interference.

If these features could be implemented, potential system design improvements would include:

- Off-line Stations — Stations could be constructed on turn-outs, as shown in Figure 1, where they do not interfere with through traffic. System capacity increases dramatically, and point-to-point service becomes feasible.

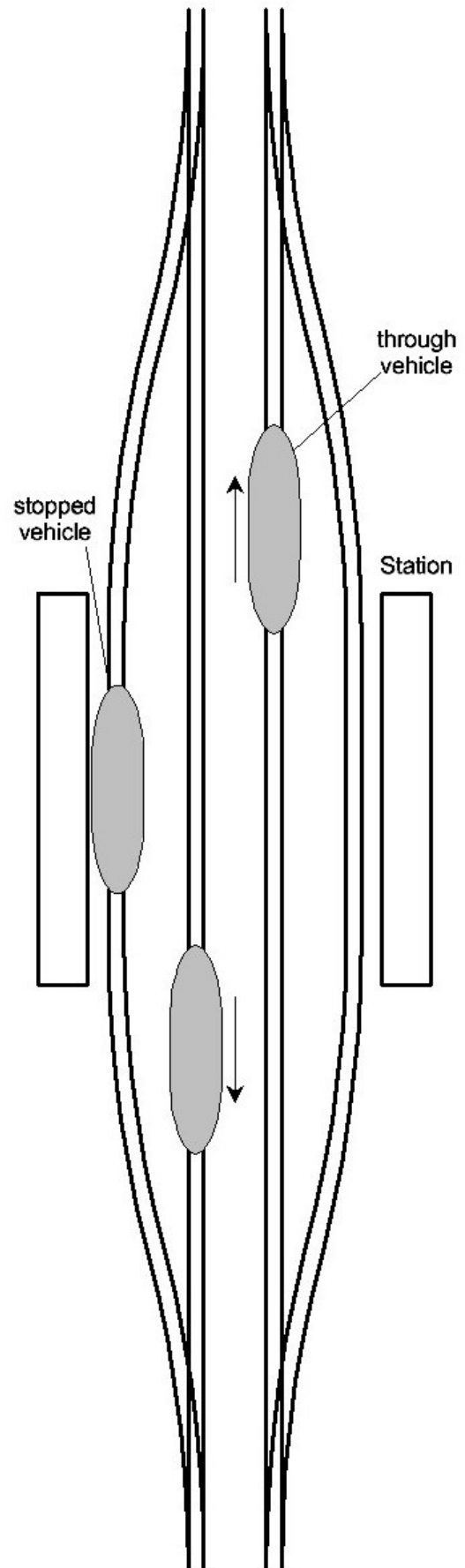


Figure 1. Off-line transit stations

- **Unidirectional Lines** — Instead of building two tracks on each link, one for each direction, connections could be unidirectional, as shown in Figure 2. This expands geographic coverage while minimizing costs. Flexible routing and scheduling would more than make up for some increases in traveling distance.

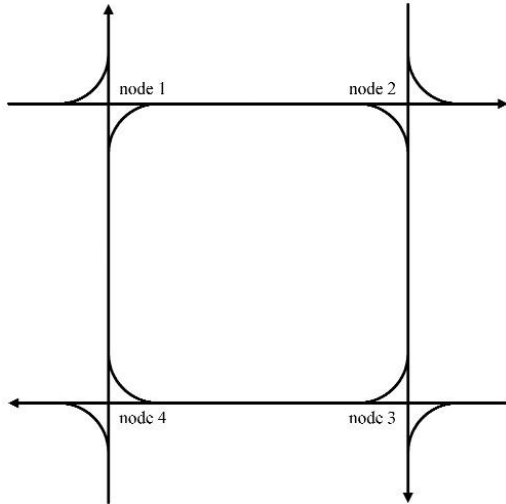


Figure 2. Unidirectional transit lines

- **Network Routing** — Instead of one high cost line, many low cost connections could be distributed throughout a region, as shown in Figure 3, vastly broadening the market and improving system reliability.

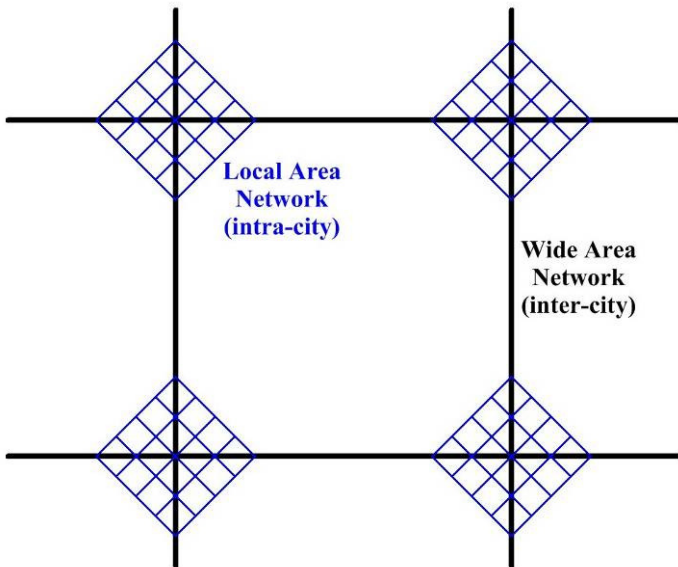


Figure 3. Network topology

Low speed “local area networks” could be used in dense urban areas, with higher speed inter-city lines.

- **Smaller Vehicles** — without the need to carry operators or run “in train”, vehicles could be

shrunk to a fraction of the size and weight of railroad vehicles, with lower manufacturing cost per seat.

- **Reduced Initial Investment** — Lightweight vehicles would result in lighter guideways and sharply reduced initial investment requirements. Networks could start with a few links in the most promising locations, and expand from there.
- **Lower Energy Costs** — Small size also would produce lower drag and higher energy efficiency, further reducing operating costs.
- **Faster Acceleration** — Lighter vehicles would allow faster acceleration at reasonable power levels, as well as better braking.
- **Shorter Headway** — Lighter weight and better braking capability would allow vehicles to follow one another at much closer distances without endangering lives.
- **Higher System Capacity** — High acceleration, short headway, network connections and point-to-point service would allow higher utilization efficiency, far higher carrying capacity and an immensely more enjoyable experience for riders.

These changes would reinforce each other in a new synergy. Costs would plummet, performance would greatly improve, and the available market would increase. Unlike maglev trains, maglev *networks* have the potential for a high return on investment.

3 A MAGLEV SWITCH IMPLEMENTATION

LaunchPoint Technologies, Inc., in collaboration with Applied Levitation, LLC and Fastransit, Inc., has designed and constructed a sub-scale maglev test track using Stabilized Permanent Magnet (SPM) suspension (Long 2008). The basic suspension design is shown in Figure 4 (Fiske 2006).

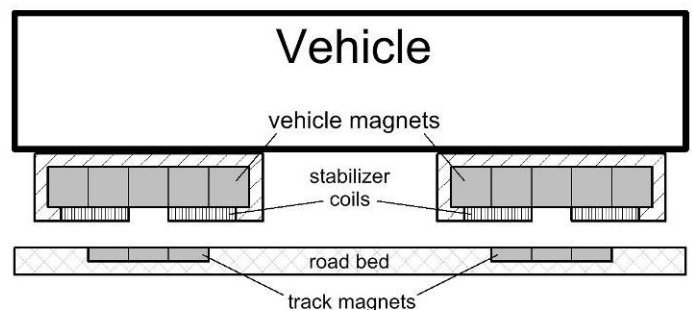


Figure 4. SPM Maglev suspension design



Figure 5. Sub-scale SPM Maglev test track

The test track includes two switches, a linear synchronous motor (LSM), and a maglev vehicle with radio control. The track and vehicle are shown in Figure 5.

The track switches are totally passive—they have no mechanical or electric components. Vehicle track switching is accomplished by the vehicle on-board control system, which manipulates the suspension stabilization fields in response to commands provided via the radio control. The operator simply presses a button on the control unit to indicate whether the vehicle should take the left track or the right track in the next bifurcating switch. Merging, where two tracks combine into one, is handled automatically.

The vehicle is shown in operation in Figure 6. The magnified view of one of the vehicle bogies in Figure 7 shows the levitation gap.



Figure 6. SPM Maglev vehicle in operation



Figure 7. Magnified view of SPM Maglev vehicle bogie

Tests of vehicle operation have demonstrated the effectiveness of this design. No impediments to larger scale implementations were encountered.

4 FUTURE IMPLEMENTATIONS

Full scale implementations are planned in the near future, with several target applications. A Group Rapid Transit (GRT) implementation is depicted in Figure 8.

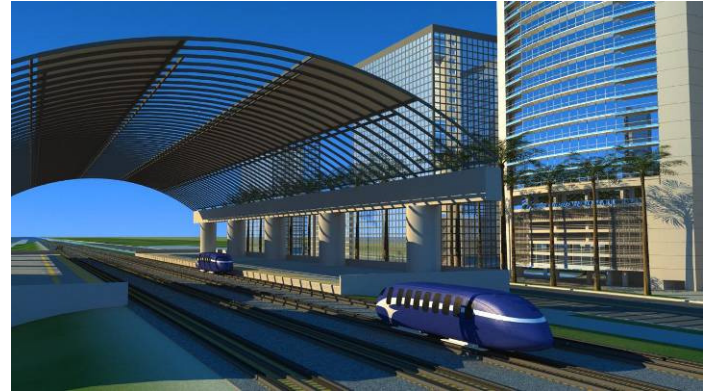


Figure 8. SPM Maglev GRT station

In this application, transit vehicles would typically accommodate 20-40 passengers. The vehicles could operate in platoons, or even “trains”, during peak traffic periods, and as single vehicles with more flexible scheduling and routing during off-peak periods.



Figure 9. SPM Maglev container transport system

Many of the arguments pertaining to passenger transport are also relevant to freight transport. An SPM Maglev container transport system is depicted in Figure 9. Here, fast switching capability provides simultaneous access to many loading/unloading stations, multiplying system carrying capacity. Containers could be transported to storage, marshalling or transfer sites within a port complex, or cross-country to distant destinations.



Figure 10. SPM Maglev PRT

A Maglev Personal Rapid Transit (PRT) implementation is shown in Figure 10. This approach exploits the capabilities of SPM Maglev even more by utilizing large numbers of very small vehicles (~4 passengers). Track costs are expected to be far below those of conventional transit systems, while automated traffic control will permit much higher system passenger capacity and superior service for riders. Urban guideways would allow vehicle speeds of 100 kph or higher, and connect with inter-city guideways where vehicle speeds could increase to 200-300 kph or more. Extended networks would offer non-stop, nearly door-to-door service over distances of several hundred kilometers, and would provide by far the highest quality personal transportation ever achieved in a mass transit system.

5 CONCLUSIONS

SPM Maglev operation has been demonstrated using a sub-scale test track, which includes two passive track switches. The capabilities of this technology will allow the construction of high speed maglev packet-switching networks. Conceptual designs of full-scale implementations for GRT, freight and PRT applications have been created, and plans for full-scale implementations are moving forward. The resulting transportation systems promise a level of service never before achieved, at a cost far below that of conventional passenger and freight transit systems.

6 REFERENCES

- FRA, Report to Congress: Costs and Benefits of Magnetic Levitation , September 2005
- Fiske O., The Magtube low cost maglev transportation system, *Maglev 2006*, Dresden, Germany, September 13-15, 2006.
- Long G., Fiske O., Paden B., Design of a Small-scale prototype for a stabilized permanent magnet levitated vehicle, *Maglev 2008*, San Diego, California, December 15-18, 2008