**Betweenness Centrality:**

* This metric of centrality measures the importance of a node in a graph node network based on the number of times it occurs in the geodesic distance or shortest path between all pairs of nodes in the graph.
* It was first formally defined by Linton Clarke Freeman in 1977.
* It attempts to capture the role of nodes as a bridge between other groups of nodes.

It is a concept derived from social network analysis but is applicable to various types of networks, including social networks, transportation networks and computer networks.

* Practically, it captures a very different kind of importance compared to other centralities: individuals controlling the flow around a network. For example, broker, controller, intermediaries, gate keeper, etc. They are the ones whose removal from the network will disrupt interactions the most.
* If we were to compare networks of different sizes, we should first normalize the betweenness centralities of those networks since larger networks generally have higher centrality scores.
* The betweenness centrality BC(v) of a vertex v in a graph is defined as:

BC(v) =

where, uw = Total number of shortest paths between node u and w.

uw (v) = Total number of shortest paths between node u and w that pass-through v.

* To normalize the BC of a vertex, we divide the BC of that vertex by the number of pairs of nodes, excluding this vertex. This rescales the BC in the range of 0 to 1.
* BC is applicable to undirected, directed as well as for a weighted network. In case of a weighted network, the shortest path is equivalent to the minimal weighted path.
* The position of a node is related to the whole network by the “flow perspective”, a different kind of importance compared to other centralities.
* Process to calculate betweenness centrality of a vertex v:

1. Calculate unique pair of nodes (unique edges)
2. Determine the shortest paths (minimal weighted paths in case of weighted graph).
3. Calculate the sum of all fractions of shortest paths through vertex v.
4. Normalize the BC

* Applications:
* In Social network analysis, BC reflects power, because they allow the person on the bridging position to exercise control. For example, twitter is a directed network and hence the flow of information or influence, for instance via a bridge (“direct connection between two people/organizations”) can be one-way to either direction or two-way. Examining the interaction between organizations and the public on Twitter, users with high betweenness centrality play a key role in reaching out to users that do not interact directly with the organization.
* In River/Water networks, BC has been used to analyze the topological complexity of river/water networks and their use in maritime trade. As a popular example from recent times, maritime chokepoints around the world are being given utmost importance. Reason being over 80% of the volume of international trade in goods is carried by sea through 4 or 5 narrow passages (choke points) of the Indian Ocean, and the percentage is even higher for most developing countries.   
    
  “Maritime chokepoints” are defined as - narrow shipping channels with high traffic because of their strategic locations. Clearly, as the name suggests, maritime chokepoints are easy to block/choke at the same time they have high traffic, meaning these points have high BC. Some of the famous maritime checkpoints around the world include The Strait of Malacca, The Suez Canal, The Strait of Hormuz, The Bab el-Mandeb, Gulf of Aden, etc.   
    
  Many countries such as US, China, India, etc. exert control over these checkpoints by establishing military bases near the choke points in order to counter-attack the “enemy” nation from blocking their trade, in case of war. This is a topic under deep discussion amid the global geo-political scenario including the China-Taiwan invasion, China’s Belt and Road Initiative to capture Hambantota port in Sri Lanka, Gwadar port in Pakistan, Doraleh port in Djibouti, Kyuakpyu port in Myanmar which are at crucial trade locations, and also form a “string” around India, often referred to as the Theory of String of Pearls, as this ports/naval bases system of the PRC appear to form a string of pearls around the Indian sub-continent and they can choke India around the neck, blocking access to any foreign trade and also can attack from their naval bases.

To be prepared to counter-attack China, India has been implementing the “Necklace of Diamond Strategy”, whereby India is also building such naval bases in partnership with friendly-nations for surveillance purposes at Duqm, Oman, Chabahar port in Iran, Changi Naval Base located at The Strait of Malacca, Sabang Port in Indonesia (at the entrance of Malacca strait), and few ports in Vietnam and Japan.

* In criminal or terrorist network: Nodes with high betweenness have a control over the data flowing among the different groups of nodes in the network, since such nodes act as bridges. In criminal or terrorist networks, nodes with high BC usually indicate the most important or involved actors. An actor with a high BC holds a favoured position in the network. Such a node has greater control over information propagation within the network and represents a bridge which can potentially be a single point of failure. Disconnecting such nodes can effectively disrupt communication within the network.
* Similarly, BC is also applicable in telecommunication, cyber-security, etc.