Cloud Radio Access Network (C-RAN) is a novel mobile network architecture which can address a number of challenges that mobile operators face while trying to support ever-growing end-users’ needs towards 5th generation of mobile networks (5G). The main idea behind C-RAN is to split the base stations into radio and baseband parts, and pool the Baseband Units (BBUs) from multiple base stations into a centralized and virtualized BBU Pool. This gives a number of benefits in terms of cost and capacity. However, the challenge is then to find an optimal functionality splitting point as well as to design the so-called fronthaul network, interconnecting those parts. This thesis focuses on quantifying those benefits and proposing a flexible and capacity-optimized fronthaul network. It is shown that a C-RAN with a functional split resulting in a variable bit rate on the fronthaul links brings cost savings due to the multiplexing gains in the BBU pool and the fronthaul network. The cost of a fronthaul network deployment and operation can be further reduced by sharing infrastructure between fronthaul and other services. The origins of multiplexing gains in terms of traffic burstiness, the tidal effect and various possible functional splits are analyzed and quantified. Sharing baseband resources between many cells is possible for traditional C-RANs. However, in order to further benefit from multiplexing gains on fronthaul, it is recommended to implement a functional split yielding variable bit rate in the fronthaul. For the analyzed data sets, in deployments where diverse traffic types are mixed (bursty, e.g., web browsing and constant bit rate, e.g., video streaming) and cells from various geographical areas (e.g., office and residential) are connected to the BBU pool, the multiplexing gain value reaches six. Using packet-based fronthaul has the potential to utilize fronthaul resources efficiently. However, meeting synchronization and delay requirements is a challenge. As a possible solution, the use of IEEE Precision Time Protocol (PTP) (also known as 1588v2) has been evaluated, and for the analyzed scenario it can assure synchronization on the nanosecond level, fulfilling mobile network requirements. Furthermore, mechanisms to lower delay and jitter have been identified, namely: source scheduling and preemption. An innovative source scheduling scheme which can minimize jitter has been proposed. The scheme is optimized for symmetric downlink and uplink traffic, but can also be used when downlink traffic exceeds uplink. Moreover, a demonstrator of a Software Defined Networking (SDN) controlled Ethernet fronthaul has been built.